KPMG Peat Marwick Stevenson & Kellogg
Management Consultants

Project Report

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OZONE DEPLETING GREENHOUSE GASES: PART I—BRITISH COLUMBIA INVENTORY AND EMISSIONS

Prepared for

B.C. Ministry of Environment
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Greater Vancouver Regional District

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I

Executive Summary

Through interviews with manufacturers, distributors, users and the service sectors, we have compiled a quantitative assessment of banked volumes, annual consumption and emissions for the following substances:

- CFCs.
- HCFCs.
- Halons.
- Methyl chloroform.
- Carbon tetrachloride.

Unfortunately, the main CFC manufacturer, DuPont, was not able to provide quantitative data. Consequently, data was collected from a variety of sources including equipment users, the service trades, wholesalers and system manufacturers. Quantitative estimates are presented based on our interviews. The data is presented by application and includes the total ODP weighted and GWP weighted emissions. Our estimates, which should be considered as rough estimates in many cases, are summarized in Exhibit I-1.

Exhibit I-1
Summary of 1990 data for British Columbia (tonnes)

	Total Banked	Consumption	Emissions	ODP Weighted	GWP Weighted
1. CFCs and HCFCs					
Air Conditioning					
a) Domestic					
CFC-12	25.0	2.0	2.5	2.5	2.5
b) Mobile					
CFC-12	734.0	293.0	293.0	293.0	293.0
c) Commercial					
CFC-11	119.0	22.0	18.0	18.0	6.1
CFC-12	63.0	11.0	11.0	11.0	11.0
HCFC-22	378.0	114.0	76.0	3.8	7.4
Sub-Totals:					
CFC-11	119.0	22.0	18.0	18.0	6.1
CFC-12	822.0	306.0	306.5	306.5	306.5
HCFC-22	378.0	114.0	76.0	3.8	7.4
Combined				328.3	320.0
Refrigeration					
a) Domestic					
CFC-12	452.0	52.0	69.0	69.0	69.0
b) Food service					
CFC-12	158.0	32.0	32.0	32.0	32.0
HCFC-22	79.0	40.0	16.0	0.8	1.6
R-502	79.0	24.0	16.0	5.4	17.6
c) Grocery stores					
CFC-12	129.0	26.0	26.0	26.0	26.0
HCFC-22	122.0	49.0	24.0	1.2	2.4
R-502	179.0	54.0	36.0	12.2	39.6
d) Industrial & wholesale					
CFC-12	12.0	2.4	2.4	2.4	2.4
HCFC-22	4.0	2.4	0.8	0.04	0.08
R-502	22.0	6.6	4.4	1.5	4.8

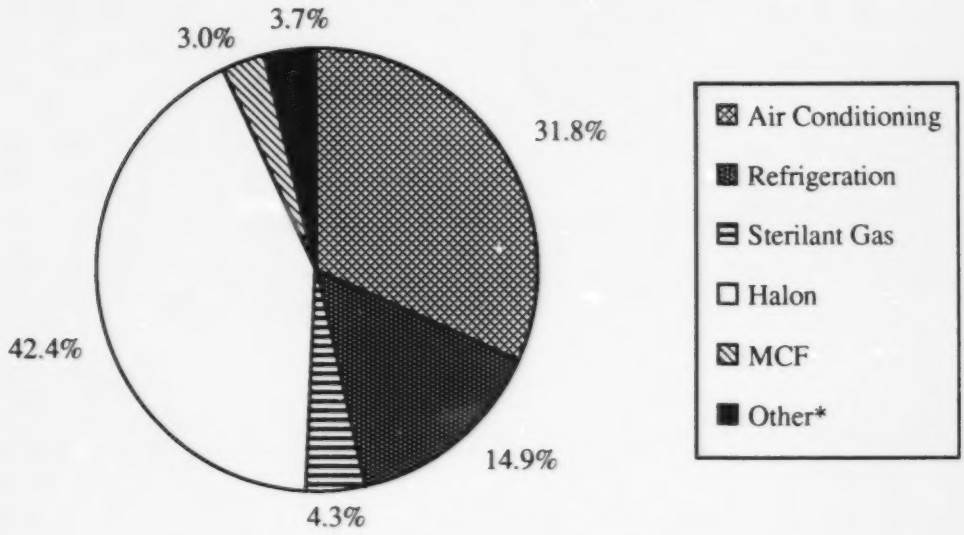
Exhibit I-1
Summary of 1990 data for British Columbia (tonnes) (continued)

	Total Banked	Consumption	Emissions	ODP Weighted	GWP Weighted
e) Marine					
CFC-12	5.7	1.3	1.3	1.3	1.3
HCFC-22	21.4	5.5	3.2	0.16	0.31
R-502	2.7	0.6	0.4	0.14	0.44
f) Mobile					
CFC-12	7.4	1.5	1.5	1.5	1.5
Sub-Totals:					
CFC-12	764.1	115.2	132.2	132.2	132.2
HCFC-22	226.4	96.9	44.0	2.2	4.4
R-502	282.7	85.2	56.8	19.2	62.4
Combined				153.6	199.0
Flexible Foam					
CFC-11	U/K	21.0	21.0	21.0	7.1
Rigid Foam					
CFC-11	U/K	75.0	7.5	7.5	2.6
HCFC-22	U/K	303.0	30.3	1.5	2.9
Sterilant Gas					
CFC-12	N/R	44.0	44.0	44.0	44.0
Solvent					
CFC-113	—	20.0	10.0	8.0	4.9
TOTALS:					
CFC-11	119.0	118.0	46.5	46.5	15.8
CFC-12	1,586.1	465.2	482.7	482.7	482.7
CFC-113	—	20.0	10.0	8.0	4.9
HCFC-22	604.4	513.9	150.3	7.5	14.7
R-502	282.7	85.2	56.8	19.2	62.4
Combined				542.9	573.4
2. Halon					
1301	210.0	15.0	31.5	315	25.2
1211	300.0	3.0	41.0	123	N/R
TOTAL	510.0	18.0	72.5	438	25.2
3. Methyl Chloroform	–	350.0	280.0	30.8	2.1
4. Carbon Tetrachloride	–	2.0	0.08	0.09	0.01

N/R = Not Relevant
U/K = Unknown

The relative distribution by application of ODP weighted emissions is presented in Exhibit I-2. Although the quantity of halons emitted is much less than that of coolants used in refrigeration or air conditioning, halon's high ODP values make it the number one contributor to ozone depletion. It contributes 42% of the total, compared to air conditioning at 32% and refrigeration at 15%. The other applications are all less than 5%.

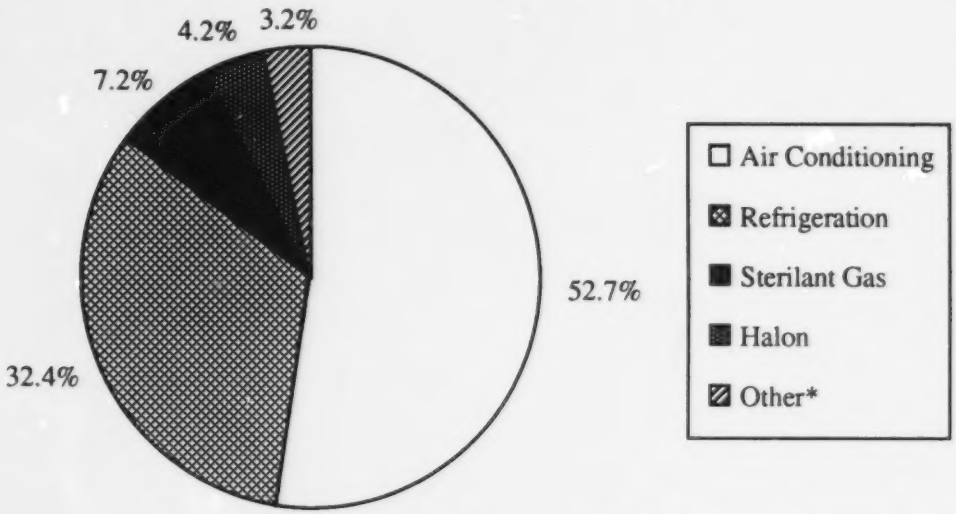
Exhibit I-2
1990 ODP weighted emissions in British Columbia



**Includes foams, CFC-113 solvent and CTC.*

Exhibit I-3 presents the relative distribution of GWP weighted emissions by application. The pie chart shows that air conditioning systems produced almost 53% of the emissions in 1990 followed by refrigeration systems at 32%. The other categories include sterilant gas at 7.2%, halon at 4.2% and the remaining applications at a combined total of 3.2%.

Exhibit I-3
1990 GWP weighted emissions in British Columbia



**Includes foams, CFC-113 solvent, MCF and CTC.*

II

Introduction

This report presents the findings of our study on the inventory and emissions of the following substances in British Columbia:

- Chlorofluorocarbons (CFCs).
- Hydrochlorofluorocarbons (HCFCs).
- Bromofluorocarbons (Halons).
- Methyl chloroform (MCF).
- Carbon tetrachloride (CTC).

HCFCs are discussed incidentally when they appear as replacements for CFCs in specific applications. All other substance groups are discussed in separate chapters of this report. The use of these chemicals in federal buildings in the Yukon is presented in Appendix 1.

The substances are discussed by application (e.g., commercial air conditioning, sterilant gas) and, in each case, we present estimated values for quantities banked, annual consumption and annual emissions for the base year 1990. In all cases quantities are reported in kilograms (kilos) or metric tonnes. The data is also provided by regional district where appropriate. We also provide estimates of the ozone depleting potential weighted emissions (ODP weighted emissions) and greenhouse warming potential weighted emissions (GWP weighted emissions) by application. (The reader should note that ODP and GWP are relative numbers only and are calculated based on tonnes. ODP is relative to CFC-11 and GWP is relative to CFC-12.) A complete list of substances and their respective ODP weighted emissions and GWP weighted emissions is presented in Exhibit II-1.

This document should be recognized as a starting point only. To the best of our knowledge, this is the first attempt to quantify consumption and emissions of these chemicals for any jurisdiction in Canada. In many cases our figures represent gross estimations only and should be viewed accordingly.

Exhibit II-1
List of ODP and GWP values

Substance	ODP[1]	GWP[2]
CFCs		
CFC-11	1.0	0.34
CFC-12	1.0	1.0
CFC-13	0.45	-
CFC-111	-	-
CFC-112	0.96	-
CFC-113	0.80	0.49
CFC-114	1.0	1.50
CFC-115	0.60	2.80
HCFCs		
HCFC-21	0.04	0.10
HCFC-22	0.05	0.098
HCFC-31	0.05	0.10
HCFC-121	-	-
HCFC-122	-	-
HCFC-123	0.02	0.0064
HCFC-124	0.02	0.10
HCFC-131	-	-
HCFC-132b	0.05	0.02
HCFC-133a	0.05	0.02
HCFC-141b	0.10	0.029
HCFC-142b	0.06	0.11
HCFC-151	-	-
HCFC-225ca	-	-
HCFC-225cb	-	-
HFCs		
HFC-23	0	-
HFC-32	0	-
HFC-41	0	-
HFC-125	0	0.10
HFC-134a	0	0.039
HFC-143a	0	0.34
HFC-152a	0	0.0091
HFC-161	0	-
Common Azeotropic Mixtures (CFCs and HCFCs)		
CFC-500-(CFC12/HFC152a-(73.8/26.2 wt%)	0.74	0.76
CFC-501-(CFC12/HCFC22-(25/75 wt%)	0.30	0.30
CFC-502-(HCFC22/CFC115-(48.8/51.2 wt%)	0.34	0.5-1.6[3]
CFC-503-(CFC13/HCFC23-(59.9/40.1 wt%)	0.27	-
CFC-504-(HCFC32/CFC115-(48.2/51.8 wt%)	0.31	-

Exhibit II-1 (continued)
List of ODP and GWP values (continued)

Substance	ODP	GWP
Bromofluorocarbons (Halons)		
HALON-1211	3	-
HALON-1301	10	0.8
HALON-2402	6	-
Fluorocarbons (FCs)		
FC-14	0	-
FC-116	0	-
Carbon tetrachloride (CTC)	1.11	0.12
Methyl chloroform (MCF)	0.11	0.0074

Source: United Nations Environment Programme Report of the Technology Review Panel (pursuant to the Montreal Protocol), June 1989.

"-" = Negligible or not available.

[1]*Relative to CFC-11*

[2]*Relative to CFC-12*

[3]*In this study we assume a GWP value of 1.1.*

III

Study Constraints And Research Methodology

Each sector studied has a unique system of sales channels and service organizations. This reflects the diversity of operating requirements, chemicals used, and so on. For example, for refrigeration and air conditioning systems, many of the units are imported fully charged from the United States. This makes it difficult to keep track of chemical quantities installed per system. Further, many systems are subsequently customized. For example, a reciprocal cooler in a large commercial building may require the addition of thirty or forty metres of interconnecting pipe, all of which must be fully charged with coolant.

Historically, very few purchasers have either been aware of, or cared about the volume of chemicals in their machines. Their concern has been to have a machine in place that provides efficient service in a cost effective manner. In most cases only the individual who installs and/or services the machine knows the coolant capacity.

Due to the increased environmental awareness of the impact of substances studied in this report, some of the larger organizations in both the private and public sector are starting to develop an inventory of their refrigeration, air conditioning and fire fighting systems. For the most part, however, they have tracked down data on the large installations only. While this may represent upwards of 75% of the total banked CFCs, HCFCs and halons in the organization, it may represent only 10-20% of the total number of machines. The emissions from the large machines may be accurately recorded, whereas the emissions from the smaller machines often remains a mystery. In view of these realities, we have approached substance and hardware manufacturers, distributors, installers, service organizations and major users for their help in describing the size and nature of their respective niche or consumption patterns.

While this approach provided us with some good general information about the various systems, they were often unable, and in some cases unwilling, to provide us with quantitative information. Reasons for this include:

- No records on what has been installed and sold in the past.
- No information recorded on the capacities of installed systems.
- Did not wish to disclose sensitive information.
- Already felt they were providing enough information to government.

In many cases, we have developed a "typical" system configuration for a particular sector which assumes certain substance types and standardized quantities—e.g., x kilos of CFC per square foot of assumed space to be cooled. Although the application of "standard" formulas is quite accurate for some applications—e.g., for refrigerators and mobile air conditioners—the trades are quick to point out that there is no such thing as a "typical" system for commercial applications. Every installation has unique requirements and final design specifications.

In each application we have relied on industry rules of thumb, where they exist, plus whatever hard quantitative data we could locate. For example, when assessing commercial air conditioning we used the industry standards of 450 square feet of area cooled per tonne of capacity and 1.5 kilos of coolant per tonne. We obtained estimates for the total amount of commercial space in the province, estimated the portion with air conditioning and extrapolated accordingly. We developed a split of the alternative CFCs and HCFCs for the application based on discussions with the service trades and equipment manufacturers.

In each application we extrapolated where necessary and estimated the uncertainty of our estimates based on the variance that arose in our interviews and other data collection processes.

The respective levels of uncertainty are presented in each application along with major assumptions. In some cases we obtained data from a few players who constituted that majority of the market. In these cases we extrapolated to generate the total sector quantities and did not present assumptions.

IV

CFCs

CFCs are used for a wide variety of consumer and commercial products. They are produced in Eastern Canada and the United States primarily by DuPont and Allied Chemicals. With the exception of a few large accounts that receive bulk shipments by rail, the vast majority of product is shipped to British Columbia by truck in cylinders ranging from 15 kilos to one tonne capacity.

A. Air conditioning and refrigeration

This sector is perhaps the hardest to acquire accurate data. There are tens of thousands of installations in British Columbia ranging from home air conditioners, or "window shakers," containing less than a kilo of coolant, through to chillers in commercial buildings that hold a few thousand kilos of coolant. In between are vehicle air conditioning and refrigeration systems, mobile systems, marine systems, and a multitude of air conditioners and refrigeration systems in restaurants, pubs, hotels, corner grocery stores, supermarkets, food processors, distributors, and so on.

1. Air conditioning

Air conditioning systems are discussed for the following applications:

- Domestic (e.g., window shakers).
- Mobile (e.g., cars and light trucks).
- Commercial (e.g., offices, shopping centres, restaurants,and hotels).

a) Domestic air conditioners

Domestic air conditioners consist primarily of "window shakers" that contain 0.4 to 1.5 kilos of CFC-12. Some home owners have installed larger central units or heat pumps, although these are considered rare in British Columbia.

Based on interviews with major manufacturers and retailers, our estimate of the current sales of domestic air conditioners is 8,000 units per year, amounting to 4 tonnes of CFC-12. Further, the standing stock or banked quantity is about 25 tonnes of coolant.

These machines are sealed units and have an estimated mean emission rate of 10% per year or 2.5 tonnes of CFC-12. Essentially all of these machines are brought into British Columbia fully charged. Thus, the annual consumption within the province is limited to the servicing requirements. Industry participants indicate that about two tonnes is used each year in servicing this market. The remaining emissions are from decommissioned units, e.g., following a mechanical failure and resulting discharge, the machine is thrown out rather than repaired.

b) Mobile air conditioning

Vehicle manufacturers are in the process of switching coolants from CFC-12 to HFC-134a. The latter is being introduced in 1% to 2% of the 1991 model cars and should fully replace CFC-12 by 1995. For the sake of our inventory, the sole coolant is CFC-12.

To estimate the incidence of air conditioners in cars and light trucks we started with a listing of the total number of cars, by make and model year, registered in British Columbia for the model years 1977 to 1991. We then obtained estimates of the incidence of air conditioners sold for each model year from industry representatives. In general, the factors affecting the sale of air conditioners in vehicles sold in British Columbia include:

- British Columbia residents buy a higher percentage of compact cars than those in the rest of Canada. Historically, these cars do not come with air conditioning as a standard item.

- The climate in much of British Columbia is milder than other parts of the country, thus there is less demand for air conditioning relative to other areas in Canada.

- With an increased focus on streamlining, the newer cars are using far more glass in the manufacture of cars. To mitigate excessive heat build-up inside the vehicle, manufacturers are increasingly turning to air conditioning as an essential component of the "climate control system."

- With increased competition, many manufacturers have recently begun to include air conditioning as a free option (versus the normal purchase price of $1,000-$1,500) to lure customers.

The outcome is that national sales figures for North American and Japanese are currently approaching 80% of non-fleet sales with air conditioners, with British Columbia lagging by 5-10%. (Fleet sales, which account for about 25% of the volume of North American cars, currently run at about 40% sold with air conditioners.) This compares to sales of air conditioners of about 10% and 5%, respectively, for fleet and non-fleet in the late 1970s.

A large percentage of the European cars sold in British Columbia fall into the higher end or luxury class and have always had a higher incidence of air conditioning. Further, light truck sales, which account for about about 26% of the total registration in British Columbia, have risen from less than 5% sold with air conditioners in the late 1970s to about 40% today.

The data is summarized in Exhibit IV-1. The table shows that of the vehicles currently registered in British Columbia, 21% of the trucks have air conditioners, compared with 37% of the cars. We estimate the accuracy of these figures to be ±20%, i.e., 21% ±4% and 37% ±7.5% for trucks and cars respectively.

Exhibit IV-1
Vehicle air conditioners (A/C) in British Columbia

	Total # Vehicles Registered*	% with A/C	Total # of Vehicles with A/C	Avg. Amount CFC-12 per Vehicle (kg)	Total Amount CFC-12 (tonnes)	Est. Rate of Emissions (%/year)	Total Emissions (tonnes/year)
Cars	1,330,014	37%	489,049	1.2	587	40%	235
Trucks	460,664	21%	97,876	1.5	147	40%	59
Total	1,790,678		586,925		734		293

Source: PMS&K estimates.

**I.C.B.C. computer printout dated November 19, 1990.*

The combined inventory of CFC-12 currently banked in cars and light trucks is estimated to be 734 tonnes. The annual consumption of CFC-12 used in servicing equals the estimated emission rate of 40% per annum. This figure is estimated at 293 tonnes. (The small after-sale installation market in British Columbia is about equal to the decommissioning losses.) This produces a corresponding ODP weighted emissions of 293 tonnes and a GWP weighted emissions of 293 tonnes.

Exhibit IV-2 presents estimated emissions, ODP weighted emissions and GWP weighted emissions by regional district. The information in this table is based on the assumption that the distribution of air conditioned vehicles is on a per capita basis throughout the province.

Exhibit IV-2
Estimated emissions of CFC-12 from vehicle air conditioners in British Columbia

Regional District	Estimated Annual Emissions (tonnes)	ODP Weighted	GWP Weighted
Alberni-Clayoquot	2.8	2.8	2.8
Bulkley-Nechako	3.5	3.5	3.5
Capital	27.2	27.2	27.2
Cariboo	5.5	5.5	5.5
Central Coast	0.3	0.3	0.3
Central Fraser Valley	7.6	7.6	7.6
Central Kootenay	4.6	4.6	4.6
Central Okanagan	9.7	9.7	9.7
Columbia-Shuswap	3.8	3.8	3.8
Comox-Strathacona	7.4	7.4	7.4
Cowichan Valley	5.4	5.4	5.4
Dewdney-Alouette	8.1	8.1	8.1
East Kootenay	4.6	4.6	4.6
Fort Nelson-Liard	0.4	0.4	0.4
Fraser-Cheam	6.2	6.2	6.2
Fraser-Fort George	8.0	8.0	8.0
Greater Vancouver	138.3	138.3	138.3
Kitimat-Stikine	3.7	3.7	3.7
Kootenay-Boundary	2.8	2.8	2.8
Mount Waddington	1.3	1.3	1.3
Nanaimo	8.6	8.6	8.6
North Okanagan	5.4	5.4	5.4
Okanagan-Similkameen	6.0	6.0	6.0
Peace River	4.7	4.7	4.7
Powell River	1.8	1.8	1.8
Skeena-Queen Charlotte	2.2	2.2	2.2
Squamish-Lillooet	2.1	2.1	2.1
Stikine	0.2	0.2	0.2
Sunshine Coast	1.8	1.8	1.8
Thompson-Nicola	9.3	9.3	9.3
Total	293.0	293.0	293.0

Source: PMS&K estimates.

Servicing

Vehicle air conditioners produce one of the highest emission rates of all air conditioners and refrigeration systems. This is because the systems are not sealed and coolant leaks out through the rubber hoses, joints, and so on. Further, vehicle air conditioners typically sit for much of the year without being used followed by a few months of intense use. Such intermittent use is hard on the system. It results in a relatively high incidence of broken seals and hoses. Also, most users service their units only when they break down (e.g., when a hose breaks and there is a resulting complete discharge of coolant), as opposed to regularly scheduled preventative maintenance. For this reason, we estimate that about 50% of the discharges occur while driving, including car accidents. The remainder is evenly split between service stations and wrecking yards. (The reader should note that no hard data exists on the location of emissions.)

To further aggravate the situation, a high percentage of the service trade is not fully trained in air conditioner maintenance and repair. This lack of education leads to a higher percentage of unnecessary discharges during servicing than experienced in other sectors. Also, the economics of servicing does not promote recycling. At the time of writing, it costs only $15-$20 (materials only) to recharge a vehicle air conditioner.

It should be noted, however, that the emission rate is starting to decrease in this sector. Many of the dealers and some of the major service facilities have recently begun to acquire and use recovery units (e.g., about one-third of the shops in the G.V.R.D. and less in other jurisdictions). The coolant can then be recovered, cleaned and reused, rather than released to the atmosphere.

ICBC estimates that about 25,000 cars and light trucks are written off or scrapped in British Columbia each year. The organization has recently begun to recover the coolant remaining in air conditioners from these vehicles. They were not able to provide quantitative data at this time.

c) Commercial air conditioning

Commercial air conditioning systems are installed in offices, retail shopping outlets, hotels, restaurants, bars, lounges and so on. Based on our discussions with industry, the approximate ratio of the groups in our study area based on total square footage is:

Offices	42%
Retail shopping centres (> 30,000 sq. ft.)	13%
Other retail (hotels, restaurants, etc.)	45%

The information provided by the trades was often not split out between the various sectors. Because of the similarities in coolant type and quantities used per square foot of space for the various commercial applications, they have been combined to facilitate research and discussion.

A significant amount of CFCs and HCFC-22 is used in office buildings, hotels, retail shops, and so on. CFC-11 is used in the large centrifugal chillers which are generally restricted to large buildings (e.g., greater than 10 stories). Roof-top machines use HCFC-22 in the newer machines and, like chillers, CFC-12 in the older systems. Heat pumps, which are popular in small buildings, also use HCFC-22 almost exclusively.

There are an estimated 350 centrifugal chillers in British Columbia. The remaining buildings have one to a few hundred packaged units, or a customized or "built-up" unit. Industry experts suggest that about 30% of the non-chiller, commercial systems in British Columbia are built-up systems. This type is the hardest to assess due to the unknown quantity of piping used in each installation. Further, every additional joint in a system increases the potential for emissions. For example, while a modular system may emit only 10% per year, a complex central system in a large supermarket may produce an annual emission rate in excess of 25%.

In terms of total square footage, there is about 117 million square feet of commercial space in the GVRD. By applying the industry rule of thumb that 70% of commercial space is within the GVRD, the total study area includes 168 million square feet of commercial space.

Our estimate of the total consumption and banked quantity of coolant in the commercial sector, based on interviews with industry participants, is shown in Exhibit IV-3.

In this table, emissions are estimated at 15% per year for chillers and 20% per year for all other systems. The annual consumption for chillers is estimated at 1.25 times emissions, i.e., chillers are charged on site at the time of installation and the industry estimates that the ratio of gas sales is 4:1 in servicing versus installation. In all other systems a figure of 2:1 has been adopted. Again, the built up systems are fully charged on site during installation. Most of the packaged units, on the contrary, are imported fully charged.

Also, the consumption of CFC-12 is estimated to equal emissions as there is essentially no OEM installation of CFC-12 systems any longer. This substance is only used in servicing older systems.

Exhibit IV-3
Use of CFCs and HCFCs in commercial air conditioners (tonnes)

	Chillers	Other Systems	Total	ODP Weighted	GWP Weighted
CFC-11					
Banked	119		119		
Consumed	22		22		
Emissions	18		18	18	6.1
CFC-12					
Banked	21	42	63		
Consumed	3	8	11		
Emissions	3	8	11	11	11
HCFC-22					
Banked		378	378		
Consumed		114	114		
Emissions		76	76	3.8	7.4
TOTAL				32.8	24.5

Source: Discussions with industry representatives

The above figures are based on industry provided rules of thumb for coolant per rated capacity (i.e., 1.5 kilos coolant per tonne, or 12,000 BTUs, of cooling capacity) and area cooled per tonne of capacity (450 square feet per tonne). Also, although the figures for centrifugal chillers are considered to be accurate (i.e., ±10%), the data for "other systems" is based on the assumption that all commercial space in the study area is air conditioned. We know that this assumption is not true, but it may be offset when industrial space is considered, i.e., we have not otherwise allowed for air conditioning in the approximately 120 Million square feet of industrial space in British Columbia. We estimate that the banked, consumed and emission figures are accurate to within ±40%.

As mentioned above, about 70% of the emissions are considered to occur in the Greater Vancouver Regional District (GVRD). Another 10-20% is in the Capital Regional District (CRD). The balance is spread throughout the province.

2. Refrigeration

Refrigeration systems are discussed for the following applications:

- Domestic (e.g., refrigerators and freezers).
- Food service (e.g., restaurants, hotels, bars, caterers, delicatessens and take-out establishments).
- Grocery stores (e.g., supermarkets and convenience stores).
- Industrial and wholesale (e.g., food packers, processors, and distributors).
- Marine (e.g., fishing boats).
- Mobile (e.g., refrigerated or "reefer" trucks).

a) Domestic refrigeration

There are an estimated 1.4 million refrigerators in British Columbia with a CFC charge (i.e., some of the old refrigerators used SO_2 or ammonia as coolant). An estimated 90% of the refrigerators are charged with CFC-12. The remainder are charged with CFC-114, HCFC-22 and R-502 (a blend of HCFC-22 and CFC-115).

There are an estimated 710,000 domestic freezers (e.g., chest freezers) in the study area. Industry sources indicate that about 90% of the freezers are charged with CFC-12. The remainder are charged with HCFC-22.

At an average charge of 0.2 kilos for refrigerators and 0.3 kilos for freezers (in both cases the amount of charge varies with age—older models having higher charges—and size of the unit). This amounts to 280 tonnes of coolant in refrigerators and 213 tonnes in freezers. The amounts banked and emitted are shown in Exhibit IV-4.

Emissions are estimated at a rate of 15% per year. This comes primarily from mechanical failure, leaks in the system and "decommissioning." Because the refrigerators sold in British Columbia are almost all imported to the province fully charged, consumption is restricted to replacing the coolant lost in emissions. Further, it is assumed that only 75% of the emissions are actually replaced by the service sector. The remaining 25% of the units are discarded.

Exhibit IV-4
Domestic refrigeration inventory and emissions (tonnes)

	CFC-12	Other CFCs and HCFCs
Fridges:		
Amount banked	260	20
Annual consumption	30	2.3
Annual emissions	40	3
Freezers:		
Amount banked	192	21
Annual consumption	22	2.4
Annual emissions	29	3
Total ODP weighted emissions	69	<3
Total GWP weighted emissions	69	<3

Note: These figures do not include the banked CFCs in the insulating foam.

Industry sources indicate that about 60,000-70,000 refrigerators are discarded in the province each year. Less than half this number of freezers are collected. About 50% of these discarded domestic appliances originate in the GVRD based on its relative population. About two-thirds of the coolant is recovered from the refrigerators and freezers that still have a charge. (Industry sources indicate that upwards of 90% of the refrigerators and freezers maintain their charge if the appliance is properly handled and transported.) While the appliance recovery firms extract the coolant, clean it and re-use it in rebuilt units, B.C. Hydro's new collection facility in Delta is holding the coolant for eventual destruction.

b) Commercial and industrial refrigeration

i) Food service

In the food service sector we have developed a table of the total number of establishments per regional district. This data is based on a report provided by the British Columbia Liquor Control Board (LCB) which lists the location and size of all licensed establishments in British Columbia.

A comparable list of unlicensed establishments, even at the municipal level, does not exist. However, discussions with a number of municipal health departments indicate that the total number of establishments ranges from 1.9 to 2.2 times the number of licensed establishments, as provided by the LCB. We have used a factor of two to generate the estimated total number of restaurants, bars, lounges, delis, caterers, cafeterias, and so on in each regional district. We have estimated the total amount and split of coolant based on discussions with major installers and service companies.

The food service industry in the province consists of 13,058 establishments (±20%). We estimate the total amount of banked refrigerants at 316 tonnes and that emissions occur at an average rate of 20% per annum. We assume the refrigerants are split as follows:

CFC-12	50%
HCFC-22	25%
R-502	25%

Total consumption is allocated at 40% to new installations and 60% to servicing. Further, there are no new installations of CFC-12.

Inventory and emission estimates are presented in Exhibit IV-5.

Exhibit IV-5
Refrigeration systems in the food service industry in British Columbia (tonnes)

	CFC-12	HCFC-22	R-502
Banked	158	79	79
Consumed	32	40	24
Emissions	32	16	16
ODP weighted emissions	32	0.8	5.4
GWP weighted emissions	32	1.6	17.6

A detailed report of emissions, ODP weighted and GWP weighted emissions by regional district is provided in Exhibit IV-6.

Exhibit IV-6
Refrigeration systems in the food service industry—emissions by regional district

Regional District	Number of Establishments	Estimated Emissions (tonnes) CFC-12	HCFC-22	R-502	Total ODP Weighted	Total GWP Weighted
Alberni-Clayoquot	208	0.4	0.2	0.2	0.5	0.7
Bulkey-Nechako	234	0.5	0.2	0.2	0.6	0.7
Capital	1,158	2.9	1.4	1.4	3.5	4.6
Cariboo	324	0.6	0.3	0.3	0.8	1.0
Central Coast	22	0.0	0.0	0.0	0.1	0.1
Central Fraser Valley	348	0.7	0.3	0.3	0.8	1.1
Central Kootenay	302	0.6	0.3	0.3	0.7	1.0
Central Okanagan	384	0.8	0.4	0.4	0.9	1.2
Columbia-Shuswap	306	0.6	0.3	0.3	0.7	1.0
Comox-Strathcona	382	0.8	0.4	0.4	0.9	1.2
Cowichan Valley	246	0.5	0.2	0.2	0.6	0.8
Dewdney-Alouette	192	0.4	0.2	0.2	0.5	0.6
East Kootenay	406	0.8	0.4	0.4	1.0	1.3
Fort Nelson-Liard	32	0.1	0.0	0.0	0.1	0.1
Fraser-Cheam	294	0.6	0.3	0.3	0.7	0.9
Fraser-Fort George	368	0.7	0.4	0.4	0.9	1.2
Greater Vancouver	4,864	14.6	7.3	7.3	17.4	23.3
Kitimat-Stikine	196	0.4	0.2	0.2	0.5	0.6
Kootenay-Boundary	208	0.4	0.2	0.2	0.5	0.7
Mount Waddington	136	0.3	0.1	0.1	0.3	0.4
Nanaimo	464	0.9	0.5	0.5	1.1	1.5
North Okanagan	254	0.5	0.3	0.3	0.6	0.8
Okanagan-Similkameen	362	0.7	0.4	0.4	0.9	1.2
Peace River	230	0.5	0.2	0.2	0.5	0.7
Powell River	100	0.2	0.1	0.1	0.2	0.3
Skeena-Queen Charlotte	162	0.3	0.2	0.2	0.4	0.5
Squamish-Lillooet	240	0.5	0.2	0.2	0.6	0.8
Sunshine Coast	110	0.2	0.1	0.1	0.3	0.4
Thompson-Nicola	526	1.1	0.5	0.5	1.3	1.7
TOTAL	13,058	31.6	15.8	15.8	37.7	50.5

Source: PMS&K estimate based on discussion with industry participants and Liquor Control Board of B.C.

ii) Grocery Stores

This sector includes the corner grocer, with a small dairy case and a few kilos of refrigerant, to the 100,000+ square foot Superstores, Save-Ons, etc. which have up to 1.2 tonnes of HCFC-22 and R-502 at a single location. In addition to the massive volume of space that must be cooled in the new breed of mega-stores, the energy efficient designs have necessitated a higher quantity of coolant per square foot than is found in the older supermarkets. Further, in the smaller (e.g., 20,000 square foot) stores the systems often consist of modular packages rather than a central system. This precludes the need for huge runs of interconnecting pipe.

Based on Statistics Canada information, research conducted by Canadian Grocer Magazine and discussions with installers and major retailers, we estimate that there is 430 tonnes (±35%) of coolant banked in this sector. The distribution of the coolant is estimated as shown in Exhibit IV-7.

In this table we have assumed that emissions are 20% of the amount banked and that total consumption is split 40/60 between installations and servicing. Further, installation work is limited to R-502 and HCFC-22.

Exhibit IV-7
Refrigeration status in grocery stores (tonnes)

	CFC-12	HCFC-22	R-502
Banked	129	122	179
Consumption	26	49	54
Emissions	26	24	36
ODP weighted emissions	26	1.2	12.2
GWP weighted emissions	26	2.4	39.6

iii) Industrial and wholesale applications

Food processing, warehousing and distribution operations use a variety of coolants. Many of the large installations that require sub-zero temperature maintenance use ammonia systems. This includes the major fish processing plants and many of the dairy operations, for example. The ammonia systems were not reviewed as part of this study.

In addition to safeguarding perishable items, refrigeration systems are also required in such applications as lumber dryers, which typically run on HCFC-22.

Like the categories discussed above, CFC-12 was employed in the older systems. HCFC-22 and R-502 are used in the newer systems. Based on discussions with a number of the major system design and installation firms, we estimate 38 tonnes (±40%) of coolant currently banked in this sector, with an average emission rate of 20% per year. The inventory data is presented in Exhibit IV-8.

Exhibit IV-8
Industrial plus wholesale use of coolants in refrigeration systems (tonnes)

	CFC-12	HCFC-22	R-502
Banked	12	4.0	22.0
Consumption	2.4	2.4	6.6
Emissions	2.4	0.8	4.4
ODP weighted emissions	2.4	0.04	1.5
GWP weighted emissions	2.4	0.08	4.8

iv) **Marine**

The fishing fleet in British Columbia uses a combination of HCFC-22 for coolers plus CFC-12 and R-502 for freezers. B.C. Ferries use a combination of CFC-12 and HCFC-22 in their refrigeration systems. The estimated marine inventory in British Columbia is presented in Exhibit IV-9.

Exhibit IV-9
Marine use of coolants in refrigeration systems (tonnes)

	CFC-12	HCFC-22	R-502
Amount banked	5.7	21.4	2.7
Consumption	1.3	5.5	0.6
Emissions	0.9	3.2	0.4
ODP of emissions	0.9	0.16	0.14
GWP of emissions	0.9	0.31	0.44

The assumed 15% emission rate is based on discussions with industry representatives in the marine service sector and major fleet operators.. The total amount banked in fishing vessels, packers and on B.C. Ferries is considered accurate to ±25%.

v) **Mobile**

Mobile units use a combination of CFC-12 in the older units plus, in the past one to two years, HCFC-22, R-500 (a blend of CFC-12 and HFC-152a) and R-502. The first two are used for cooling, 502 is used to maintain freezing temperatures and 500 is used for both medium and low (i.e., sub-zero) temperature regimes. The charge quantity varies with the size and age of the unit. (Older units had a greater volume of coolant than the newer units.)

Industry sources estimate that 90% of the units in operation run on CFC-12 and that the volume of coolant ranges from 2 to 13 kilos. Further, the average life is about ten years and coolant is lost or emitted at a mean rate of about 20% per year. All of the new units are imported fully charged to British Columbia. Inventory and emission data is presented in Exhibit IV-10.

Exhibit IV-10
Mobile use of coolants in refrigeration systems (tonnes)

	CFC-12	Other CFCs and HCFCs
Amount banked	7.4	0.8
Consumption	1.5	0.16
Emissions	1.5	0.16
ODP weighted emissions	1.5	<0.01
GWP weighted emissions	1.5	<0.05

Industry sources indicate that most of the large service companies and many of the small organizations have invested in the small recovery and recycling units. The coolant is then extracted, filtered and replaced in the refrigeration unit. Although it is not possible to estimate the amount being recovered, it seems to be rising rapidly and, in the GVRD and CRD, is likely approaching 50% of the total volume of coolant that would otherwise be vented at servicing.

3. Servicing

A number of people in the service sector indicated to us that a number of measures could be implemented into system design to reduce emissions from, say, 20% per year to less than 5%. In many cases the changes (e.g., built in gauges, electronic controls to shut down the machine in the case of mechanical failure, welded joints) would add in the order of 10-15% to the capital cost of the equipment. The additional cost would be somewhat offset by reduced operating (i.e., servicing) costs.

Further, it was mentioned that in many sectors increased competition over the years has led to the increased use of lighter gauge and/or cheaper materials that may be more prone to leaking, corrosion, etc. For example, we were told that the old round edge domestic refrigerators do not leak coolant whereas many of the newer models are coming in for repairs and a full recharge in three to four years.

Mandatory certification and upgrading programs for mechanics including education on the need for an operation of recovery systems would also help reduce emissions.

These issues are elaborated on further in the companion report to this.

B. Flexible foams

Polyurethane flexible foam is used for furniture, transportation and rug underlay as well as molded applications. CFC-11 is often used as an auxiliary blowing agent in the manufacturing process.

There are two flexible foam manufacturers in British Columbia. Both point sources are in the GVRD and use CFC-11 as a blowing agent in their process. The total consumption of CFC-11 by the two companies in 1990 was reported to be 21,000 kilograms.

No additional sources of CFC-11 used as a blowing agent for flexible foams in the study area were identified. Further, the companies described reported that they were actively looking at alternatives to CFC-11 and hoped to switch to other blowing agents by late 1991 or early 1992.

With respect to emissions, about 25% of the CFC-11 is emitted during the production phase. The remaining 75% is released within 24 hours after production in what is known as the "curing" stage. Because the product is manufactured and cured at the same site, virtually 100% emission occurs at the plants.

The corresponding ODP weighted emissions is 21 tonnes and GWP weighted emissions is 7.1 tonnes.

C. Rigid foam

Rigid foam manufacturers frequently use CFC-12 as a blowing agent in the manufacturing process. Unlike flexible foam, rigid foams are closed cell products, thus much of the blowing agent is retained within the final product.

Only one major rigid foam manufacturer is in the study area. The company is in the GVRD and produces extruded polystyrene foam, primarily for the food packaging industry. The company switched its process to HCFC-22 from CFC-12 in 1988. Further, it is currently running pilot studies with pentane and CO_2 as alternate blowing agents.

In 1990 the company consumed just over 300 tonnes of HCFC-22. One other firm in the study area is using HCFC-22 as a blowing agent for rigid foam. The firm is currently using about 3 tonnes of HCFC-22 per year.

Emissions, at an estimated rate of 10%, amount to about 30 tonnes per year. The remaining HCFC is trapped within the closed cell structure of the final product. The corresponding ODP weighted emissions is 1.5 tonnes and the GWP weighted emissions is 2.9 tonnes.

We have not estimated emissions from the foam trays and so on as it requires a number of assumptions that are difficult to predict. For example, is most of the product thrown out within the first 12 months after production? Then, once in the landfill, what percentage of the CFCs are released through crushing by grading machines versus those that diffuse naturally at a rate of less than 1% per year?

An additional market is rigid insulating foam used for boats, trucks, custom coolers and walk-in freezers, and so on. In the GVRD, for example, there are at least 15-20 companies offering these services. The annual consumption of CFC-11 used in blowing the rigid polyurethane foam in this sector is 75 tonnes (±20%) per year. Approximately 10% of this amount is released or emitted. The remaining CFC-11 is trapped within the closed cell structure of the finished product, thereby providing its high insulating capability.

The estimated 7.5 tonnes of CFC-11 emissions per year have a corresponding ODP weighted emissions of 7.5 tonnes and a GWP weighted emissions of 2.6 tonnes. Emissions from the finished product are estimated to occur at about 0.7% per year—a diffusion half-life of 100 years. We have not estimated this value for the standing stock of rigid foams. Additional volume of rigid foams will also be imported to British Columbia, thereby increasing the banked amount in rigid foam products.

Dow Chemical estimates that about 7,500 tonnes of extruded polystyrene boardstock (i.e., insulation) exists in Canada today. Based on our 11% share of the national population, about 825 tonnes is in British Columbia.

D. Sterilant gases

Ethylene oxide (EO) is a sterilant gas used by many hospitals and some commercial sterilizers. Due to the high degree of flammability and explosive nature of pure EO, it is

diluted with CFC-12 to produce a safe product. The two gases are mixed in a ratio of 12% EO to 88% CFC-12. This gas is referred to as 12/88. The major distributors in British Columbia are Union Carbide and Canadian Liquid Air.

Although steam is commonly used as a sterilizer, many sophisticated medical devices are made of polyvinylchloride (PVC) or polyethylene and can melt or become disformed in the high heat of steam sterilization. In these situations 12/88 is typically used.

Industry participants indicate that the 1990 sales of CFC-12 used in sterilant gas (i.e., 88% of total sale of the mixture) amount to between 40,000-48,500 kilos. For the sake of this study, we will use a figure of 44,000 kilos. Due to the lack of recycling units in British Columbia, essentially all of the CFC-12 used in sterilant gas is also emitted. Thus, there is an ODP weighted emissions value of 44 tonnes and a GWP weighted emissions of 44 tonnes.

With respect to the regional distribution of consumption, the figures are biased toward the GVRD. This is because, in addition to having about 50% of the provincial population, a disproportionately high percentage of high tech plastic hospital equipment, plus the bulk of the commercial sterilizers exist in the GVRD. The GVRD therefore accounts for almost 60% of total sales in the province. It is estimated that about 15% of the 12/88 is consumed in the CRD and the rest is scattered around the province, primarily in major centres. Many hospitals, particularly in small towns, continue to use steam for sterilization rather than the more expensive 12/88 systems.

E. Solvent

CFC-113 is used as a solvent in the high-tech manufacturing trade. The known applications include cleaning electronics, computer equipment and various medical and pharmaceutical products.

Due to the lack of high-tech manufacturing in British Columbia and increasing environmental awareness, there is very little consumption of CFC-113 for use as a solvent. DuPont has stated that CFC-113 solvent accounts for less than 1% of their total CFC sales in British Columbia. Allied is the other major producer supplying British Columbia and claims to sell a similar amount to DuPont.

Estimated sales of the product in the study area amount to about 20 tonnes. At an estimated emission rate of 50%, about 10 tonnes are released to the atmosphere at present. This represents an ODP weighted emissions of 8.0 tonnes and a GWP weighted emissions of 4.9 tonnes.

Industry sources indicate that many firms employ filtration systems to clean the solvent for subsequent reuse. When the desired qualities are ultimately lost, the solvent is shipped out for destruction or to be put through an elaborate recycling process. These functions are most often performed at facilities in the United States.

V

Halons

Halons have a significant impact upon the ozone layer. Relative to CFC 12, Halon 1301 has an ODP of 10 and Halon 1211 has an ODP of 3. Because of the large quantities in which it is used and its higher ODP value, Halon 1301 accounts for 89% of all Halon ozone depleting potential.

Halon 1301 and Halon 1211 are used in total flooding systems and portable fire extinguishers. Halons are imported by DuPont, ICI, Atochem Canada Inc., and Great Lakes Chemical Corp. They are shipped into British Columbia by truck and train in containers weighing up to one tonne. Halon systems have been installed over the last 10-20 years, to protect valuable computer and communication equipment as well as libraries, stores of paper records and museums. However, the system installers we have spoken to indicated that over the last 18 months very few halon systems have been installed. The two main reasons for this are increased concern for the environmental impact of halon and the increasing cost of Halon 1301 and 1211.

A. Inventory

1. Halon 1301

Even though we could not obtain quantitative information from suppliers, they did assist us in identifying the major users of halon systems in British Columbia. These users include federal and provincial governments, crown corporations, utilities and the air transportation sector. We contacted the major users and present the summary data in Exhibit V-1

Exhibit V-1
Halon inventory and emissions for nine major British Columbia users (tonnes)

Halon 1301	
Banked	145.0
Released	9.1
Halon 1211	
Banked	19.1
Released	0.8

Estimates of British Columbia's banked Halon 1301 can also be derived from National Consumption data. In 1988, Canada used 300 metric tonnes of Halon 1301. An estimated 231 tonnes (77%) was banked. If we assume that over the 18 years of Halon 1301 system installation, on average 110 metric tonnes per year of Halon 1301 were banked in Canada, then to date 1,980 tonnes of Halon 1301 have been banked in Canada. If we assume that British Columbia's share is proportional to its share of the Canadian population, 11% of the Canadian total, approximately 218 metric tonnes of Halon 1301 are banked in British Columbia. Our survey of the province's largest users of Halon 1301 accounts for 145 metric tonnes of the 218 tonne total (66%).

Based on our survey of major users and Canada's 1988 Halon 1301 consumption figures, an estimate for British Columbia of between 180 and 220 metric tonnes seems reasonable. We believe we have captured the most significant users and to calculate emissions we will assume 210 metric tonnes of banked Halon 1301.

2. Halon 1211

Halon 1211 is mainly used in portable fire extinguishers in a variety of situations. Local distributors and suppliers of portable fire extinguishers did not provide us with good information about 1211 equipment in British Columbia and Yukon. We therefore focused on the major 1301 users, assuming they were also the major 1211 users. Like Halon 1301, Halon 1211 is being replaced by other substances. B.C. Ferries indicated to us that they have removed all 1211 extinguishers from their vessels. The only halon system they currently have is a small Halon 1301 system in their central computer room.

Only British Columbia Buildings Corporation and the Department of National Defence provided us with inventory information on banked Halon 1211.

We also obtained information on Canada's use of Halon 1211 in 1988. The results are as follows.

Use	Amount Metric Tonnes	%
Controllable emissions	50	12.0%
Fires	21	5.0
Banked	349	83.0
Total	420	100.0%

If we assume that British Columbia's share of Canada's banked Halon 1211 is 11%, then in 1988, 38.4 metric tonnes of Halon 1211 were banked in the province. Our research indicates, however, that 1988 was likely the peak year for sales. Further, in the 18 years since Halon 1211 has been on the market, there has been steady growth in sales from nothing to a peak in 1988 when the Montreal Protocol was enacted. If we assume that an average of 20 tonnes per year were banked in British Columbia between 1972 and 1990, then approximately 360 metric tonnes of Halon 1211 are

banked in British Columbia. Because British Columbia has a lower rate of industrialization than represented by our 11% portion of the national population, we have scaled this figure down. We are consequently using 300 metric tonnes for calculating emission rates.

B. Emissions

1. Halon 1301

Halon 1301 emissions occur for the following reasons:

- Use to suppress fire.
- System and appliance testing and training.
- Accidental discharge and leakage.

Data from B.C. Tel indicates that over the last 14 years roughly 7% of their 1991 Halon 1301 stock has been known to be discharged. This represents a discharge rate of 0.5% per year.

B.C. Transit indicated to us that over the last four years a total of 464 kilograms of Halon 1301 has been accidentally discharged. This represents nearly 20% of their total stock, a discharge rate of 5% per year.

These discharge rates are quite favourable when compared to Canada-wide usage of Halon 1301. A 1988 study revealed the following uses for Halon 1301 in Canada in 1988.

Banked	70.7%
Fire suppression	4.1
System tests and service	11.7
Accidental discharge	5.9
Other	7.6
Total	100.0%

Based on this information and the information we have from B.C. Tel and B.C. Transit, an annual emission rate of 15% of banked Halon 1301 is not unreasonable. This is higher than both the B.C. Tel and B.C. Transit rates. Reasons for this higher rate include:

- B.C. Tel and B.C. Transit are probably more careful than other users.
- The B.C. Tel and B.C. Transit rates do not account for emissions at the Halon 1301 production or distribution stages.

- B.C. Tel and B.C. Transit only track known emissions.

We use an emission rate of 15%. This is lower than for Canada as a whole, because British Columbia is probably not so affected by the emissions associated with production and initial distribution activities.

Using an emission rate of 15% based on a banked stock of 210 metric tonnes, roughly 31.5 tonnes of Halon 1301 are emitted from British Columbia. The reader should be cautioned that this is an estimate. Exhibit V-2 shows the calculated ODP weighted emissions and GWP weighted emissions of Halon 1301 and 1211.

Estimated annual consumption for 1990 is less than the amount emitted, because once expended, halon chemicals, especially 1211, are not replaced.

Exhibit V-2
Ozone depleting potential and global warming potential of estimated halon emissions in British Columbia (tonnes)

	Halon 1301	Halon 1211
Amount banked	210.0	300.0
Consumption	15.0	3.0
Emissions	31.5	41.0
ODP weighted emissions	315.0	123.0
GWP weighted emissions	25.2	N/R*

Note: N/R—not relevant. No GWP specified for Halon 1211.

2. Halon 1211

Very little emission data for British Columbia is available. The only data we did collect on Halon 1211 was from B.C. Transit. Interestingly, they told us that each year an estimated 273 kilograms of 1211 is consumed because portable extinguishers are stolen for the narcotic effect of Halon 1211. B.C. Transit does not know whether all stolen extinguishers result in total discharge. However, the appliances recovered are often empty.

To estimate emissions, if we agree with the findings for Canada in 1985, that 12% of all Halon 1211 used is emitted, then emissions represent 13.6% of halon banked. Assuming there are 300 metric tonnes of banked Halon 1211 in British Columbia, approximately 41 tonnes are emitted each year. The ozone depleting potential of these emissions are shown in Exhibit V-2.

This could be an over-estimate of emissions. While a large amount of emissions take place for training, testing and transportation of product, since 1985 new guidelines on testing and training, together with the fact that very few Halon 1211 extinguishers are now being introduced, could mean that emissions are substantially less than 41 metric tonnes. Local suppliers of portable fire extinguishers have indicated to us that they currently sell very little Halon 1211 equipment. Some suppliers have even stopped carrying 1211 products.

VI

Methyl Chloroform

Methyl chloroform (MCF) is chlorinated solvent. Dow is the major Canadian producer and supplies two British Columbia distributors with methyl chloroform (low stabilized) and Chlorathene, a trade name for MCF. Chem Chemical and Vulcan U.S. also supply British Columbia with small amounts of methyl chloroform. No methyl chloroform is produced in British Columbia. It is transported into British Columbia by rail and truck.

An analysis of sales data from British Columbia's major distributor of MCF indicated the following major users (see Exhibit VI-1).

Exhibit VI-1
User share of British Columbia's MCF consumption by weight, 1990

User Type	% Share of Consumption by Weight	Estimated Total (tonnes)
Manufacturers	53.5	187
Electronic component manufacturers	11.4	40
Film laboratories	10.1	35
Automotive maintenance workshops	7.9	28
Oil companies	3.6	13
Federal and provincial government	3.1	11
Other, including laboratories	2.8	9.8
Mechanical engineering	2.5	8.8
Mining and mineral processing	1.4	4.9
Chemical wholesalers	1.3	4.6
Metal processing	1.2	4.2
Utilities	1.1	3.9
Hospitals	0.1	0.35
TOTAL	100.0%	350

The manufacturing and electronic component sectors account for nearly two-thirds of MCF consumption. Film laboratories are also quite a large user. The major applications in the manufacturing sectors are degreasing and cold cleaning.

A. Inventory

Estimated historical Canadian consumption of MCF is as follows:

1986	15,600 tonnes
1987	16,300 tonnes
1988	17,300 tonnes
1989	14,500 tonnes
1990	12,000 tonnes

Due to the small manufacturing sector in British Columbia, we use a disproportionately small portion of the national total.

We contacted the two major distributors in British Columbia. One provided us with detailed sales information. In 1990, they supplied British Columbia businesses with 277 tonnes of MCF.

The other supplier was less forthcoming with quantitative information. However, they estimated that they sold 20 to 30 metric tonnes per year in British Columbia and had about 10% of the market. Dow Chemical, the major Canadian producer of MCF indicated that they add about 330 metric tonnes to British Columbia in 1990. We therefore assume that British Columbia consumed 330-370 metric tonnes of MCF, which allows for possible imports of MCF from the United States. To calculate emissions, we will use an estimate of 350 metric tonnes.

B. Emissions

British Columbia businesses consumed roughly 350 metric tonnes of MCF in 1990. Roughly 80% of this amount is emitted into the atmosphere. The levels of emissions depend on use. Emissions for 1989 in Canada are shown in Exhibit VI-2. The remaining 20% is not emitted, either because it is recycled or rendered harmless by chemical transformation while in use. (Like CFC-113 solvent, recycling generally occurs at American facilities.)

Exhibit VI-2
1989 MCF emissions in Canada

Application	% of National Volume	% Emitted	% Recovered
Vapour degreasing	40%	70%	30%
Cold cleaning	14	100	0
Aerosols	11	100	0
Adhesives	9	100	0
Electronics	7	50	50
Chemical processing	8	50	50
Coatings	6	100	0
Other	5	100	0
Total	100%	80.5%	19.5%

If we assume that these national emissions characteristics are indicative of the situation in British Columbia, then roughly 280 metric tonnes of MCF are emitted into the atmosphere from the study area each year. Exhibit VI-3 shows the ozone depleting and weighted global warming effects of these emissions.

Exhibit VI-3
Estimated consumption and emissions of methyl chloroform in British Columbia (tonnes)

1990 consumption	350.0
1990 emissions	280.0
ODP weighted emissions	30.8
GWP weighted emissions	2.2

It should be noted that there are other chlorinated solvents being used in British Columbia that have positive ozone depleting potentials, but zero global warming potential. Examples of these solvents include perchloroethylene, methylene chloride and trichloroethylene. These substances are not considered by this study.

VII

Carbon Tetrachloride

Carbon tetrachloride (CTC) is another chlorinated solvent. It is manufactured in Eastern Canada and overseas and shipped into British Columbia by truck and rail. Its commercial use has been decreasing over the last five years because it is a carcinogen. However, in British Columbia there are three potentially significant uses:

- Used in the production of chlorine.
- Used as a cleaner for oil refining catalysts.
- Used in research laboratories.

Carbon tetrachloride was used as a wheat fumigant. However, a representative at the Alberta Wheat Pool indicated that other chemicals are now used.

A. Consumption

We encountered one chemical company that uses CTC in the production of chlorine in the GVRD. The firm uses 1.35 metric tonnes of CTC per annum.

We have contacted two oil companies operating refineries in British Columbia. One said it uses small amounts (1 kilogram) of CTC for laboratory purposes. The other indicated that it sends its dirty oil refining catalysts, which could be cleaned with CTC, to the United States for cleaning.

Chemical producers we spoke with indicated that relatively small amounts of CTC are supplied to laboratories. It is unlikely that more than two metric tonnes of CTC were consumed in British Columbia in 1990.

B. Emissions

The chlorine producer told us that their use of CTC involves minimal release to the atmosphere. A major chemical producer indicated to us that over 96% of the CTC consumed in Canada is used as a chemical intermediate and is therefore not committed to the atmosphere. The chemical production process neutralizes the ozone depleting and global warming impact of CTC. Carbon tetrachloride contributes very little to global warming and ozone depletion.

In Exhibit VII-1 the global warming impacts of CTC emissions are presented if we assume that two metric tonnes of CTC are consumed in British Columbia and that 4% is emitted to the atmosphere.

Exhibit VII-1
Estimated consumption and emissions of carbon tetrachloride in British Columbia (tonnes)

1990 consumption	2.00
1990 emissions	0.08
ODP weighted emissions	0.089
GWP weighted emissions	0.0096

Appendix 1

Inventory In Federal Buildings In The Yukon

Appendix 1

Inventory In Federal Buildings In The Yukon

According to Public Works Canada (PWC) in Whitehorse, there are seven federal buildings in the Yukon, as follows:

- Dawson City Federal Building.
- (Old) Whitehorse Federal Building.
- Five buildings in the Takhini complex in Whitehorse.

In addition, a new federal building is currently under construction in Whitehorse.

A spokesman at PWC indicated that there are no central air conditioning or refrigeration systems in any of the federal buildings in the Yukon. He suggested that there might be 10-15 small individual units, such as "window shakers," in the above buildings (which would contain less than 100 kilos of coolant in total), and that the new federal building under construction may have a central cooling system installed. There are no other reported federal uses of CFCs or HCFCs in the Yukon.

With respect to halons, the PWC contact indicated a total banked quantity of 227 kilos of Halon 1301 and no Halon 1211 portables. There have been no known 1301 emissions to date.

No CTC or MCF is reported in use in the federal buildings in the Yukon.

Appendix 2

List Of Contacts

Appendix 2

List Of Contacts

Allen, Bob—Environment Canada Whitehorse (403-667-3400)
Anderson, Gerry—Medigas Pacific Ltd. (255-4089)
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Fitzgerald, Brian—Honda Canada
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Sales Manager—Dave Buck Ford (980-2411)
Sales Manager—Happy Honda (294-2111)
Sales Manager—Kingsway Honda (873-3676)
Sales Manager—Kingsway Toyota (879-8411)
Schopman, Al—Prism Systems
Scott, Bob—Dow Chemicals
Sergies, Dave—Peter Industries (525-4691)
Service Manager—Carter Pontiac Buick (291-2266)
Service Manager—Dueck Chev. Olds Cadillac (324-7222)
Service Manager—Jubilee Plymouth Chrysler (980-8501)
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Tasman Industries (946-0458)
Toyota Canada (1-800-263-7640)
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Unwin, Graham—Haakon Industries (273-0161)
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Wadge, Charlie—AW Fire Guard and Supplies
Walker, Bruce—Sales Executive, DuPont (Western Canada) (244-2940)
Webster, Brian—Hi-way Refrigeration (294-1211)
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Whittaker, Doug—EnvironChem (re: B.C. Hydro Buyback Program) (929-0233)
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KPMG Peat Marwick Stevenson & Kellogg
Management Consultants

Project Report

OZONE DEPLETING GREENHOUSE GASES IN BRITISH COLUMBIA: PART 2— MANAGEMENT MEASURES FOR CONTROL OPTIONS AND EMISSIONS CONTROL

Prepared for

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Environment Canada
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I

Executive Summary

A. Overview

This report investigates possible control options for the various industrial sectors in which CFCs, halons, methyl chloroform, carbon tetrachloride and hydrochlorofluorocarbons (HCFCs) are used. In addition, emission control policies are reviewed for each of these sectors. The report also provides an assessment of possible management options for British Columbia.

The approach that we follow in this assessment is to provide an analysis of likely control options and emission control policies by application. In other words, we provide information, by industry, on the approaches that are being followed to reduce the use of these substances and to control emissions. This information provides a necessary starting point in considering what further control policies may be desirable.

The remainder of this chapter provides a review of control options and emission controls under the following headings:

- Refrigeration and air conditioning.
- Flexible foams.
- Rigid foams.
- Sterilant gas.
- Solvents.
- Halons.
- Methyl chloroform.
- Carbon tetrachloride.
- Hydrochlorofluorocarbons.

B. Refrigration and air conditioning

The refrigeration and air conditioning industry is working closely with suppliers in developing and testing systems based on alternative refrigerants. These refrigerants are HCFC-123 for CFC-11 and HFC-134a for CFC-12. On the air conditioning side, units using HCFC-123 are now commercially available. Commercial quantities of HCFC-134a are also available now but the transition schedule is somewhat slower for CFC-12. In addition, HCFC-22 can be used in many air conditioning and refrigeration applications.

A variety of emissions controls are feasible and are being developed in this sector. Better design of equipment, improved installation and operating procedures, better servicing and repair methods and new recycling and disposal approaches are all being implemented. This is one of the sectors in which the returns to better emission controls are greatest. Industry codes of practice are making improvements but there remains an important role for public policy particularly in the area of recycling.

C. Flexible foam

Flexible foam is used as a cushioning material and is produced either as a slabstock or as a molded product. Most of the CFC-11 that is used in this sector is to produce specific foam grades. These grades are low density foams and soft high density foams.

The most important control options in this sector are alternative blowing agents and new polyols that can produce the desired foam grades without the use of an auxiliary blowing agent.

Emissions controls are technically feasible but could be used effectively only in smaller plants with vertical foam chambers.

D. Rigid foams

The use of CFCs in this sector is to produce polyurethane foam, extruded polystyrene foam and phenolic foam. Alternative insulating materials namely fibreglass are competitive in some applications and constitute a control option but the other options are new blowing agents and new polyol systems.

In the production of extruded polystyrene insulation, most production has ben converted to a blend based on HCFC-142b. In the polyurethane sector, the alternative blowing agent is likely to be HCFC-123 or HCFC-141b. For phenolic foam, options include HCFC-123, HCFC-141b and HCFC-142b.

The nature of the production process for these foams makes emission controls technically feasible but not economically viable. These products are all closed cell and the trapped CFCs play an important role in the properties of the product. The intent is to capture as much of the blowing agent as possible in the board so that emissions are already limited.

E. Sterilant gas

CFC-12 is used as a diluent in hospital sterilant gas for use in applications where sensitive materials such as polyvinylchloride cannot be exposed to the heat of steam sterilization. Control options include the use of HCFC diluents, recycling and the use of other sterilization techniques.

Emissions controls are feasible and can be introduced with machines that now use CFC-12 and these will be compatible with new HCFC units.

F. Solvents

CFCs are used in a variety of cleaning applications including the electronics sector where circuit boards and other components are cleaned prior to final assembly. A variety of control options are being pursued to reduce consumption of CFC-113. Better conservation practices can play an important role along with alternative cleaning technologies like aqueous cleaning or no-clean fluxes.

In all areas of solvent cleaning, firms are moving to tighter cleaning systems to reduce emissions. Much progress has been made in this area in dealing with CFCs. As new cleaning systems are introduced, some of these will uses HCFCs and controlling emissions more effectively should be an objective of this transition.

G. Halons

Halon has been used extensively both in portable fire extinguishers and in fixed fire suppression systems. Sales of both types of units have declined substantially since 1990. Alternative extinguishing agents such as dry chemical or CO2 have been used in areas where the properties of halon are not essential. Commercial testing is now taking place for substitutes for halon 1211 and halon 1301 that are more of a drop-in replacement.

For emission controls most of the potential gains are for 1301 systems. Improved practices have already been implemented for discharge testing, filling, shipping and service. Effective management of the existing stock of banked halon can contribute to reduced emissions and to more effective use of the halon that is already in place.

H. Methyl chloroform

Methyl chloroform is used widely as an industrial solvent because of its low toxicity, low volatility and low flammability. No single alternative will replace its use in the applications where it is now used. Control options are similar to those for CFC-113. Tighter cleaning systems, no-clean technologies, aqueous and semi-aqueous cleaning and HCFC solvents are all likely to play roles in this area.

Emission reductions are likely to be observed as a result of better conservation practices and new cleaning systems that minimize the loss of solvent.

I. Carbon tetrachloride

Carbon tetrachloride is used as a catalyst promoter in oil refining and to remove nitrogen trichloride in the production of chlorine. Emissive uses are quite limited and available data indicate that substitutes can be used for this chemical.

J. Hydrochlorofluorocarbons

As noted throughout the preceding subsections, HCFCs will replace CFCs in a variety of applications. The HCFCs are bridging substances that will ultimately be controlled under the Montreal Protocol. Control options are not clear at this point for these substances but many emission control policies developed for CFCs will be effective for HCFCs as well.

K. Management options

Our report provides an assessment of the types of policies that could be developed to contribute to a more effective reduction schedule in British Columbia. Such policies would have to be developed to be harmonious with existing Federal initiatives. Identifying possible gaps in those measures as they apply in B.C. may be an effective way to proceed.

Many useful provincial initiatives are possible. This report focuses on the development of reporting requirements that would be necessary for most control policies and the development of sectoral control approaches. The report identifies two areas as being particularly important in an effective provincial control strategy. The first set of policies that could be developed are those that would operate within provincial departments and agencies where significant quantities of these substances are used. The other important set of policies would operate in areas where recycling initiatives are likely to be effective. The report identifies the refrigeration and air conditioning sector, the solvent sector, the hospital sector where sterilant gas is used and the fire protection sector using halon as the areas where recycling policies have the greatest potential.

II

Introduction

This report on control options and emission control strategies is a component of the overall study that we are undertaking on the inventory of ozone-depleting greenhouse gases in British Columbia The specific substances to be reviewed are:

- CFCs.
- Halons.
- HCFCs.
- Methyl chloroform (MCF).
- Carbon tetrachloride (CTC).

The format of our plan for assessing control options and emission control strategies is outlined in Exhibit II-1.

Our approach in this report deals with both the CFCs and the HCFCs by application, that is by process group and product group. The halons are dealt with under the headings of portables (1211) and total flooding systems (1301). Methyl chloroform has a variety of applications as a solvent and these are assessed as a group. A similar approach is used for carbon tetrachloride, a chemical that has relatively few emissive and controlled uses in British Columbia.

There is substantial literature on control options including a report prepared for Environment Canada that deals with the CFCs and halons. Methyl chloroform and carbon tetrachloride have been studied less in Canadian applications but extensively in the international literature. There is little available material on control options for the HCFCs that are conventionally regarded as transitional substances that will not be controlled until a later date. This report does not provide an exhaustive summary of material that is available elsewhere but does indicate for each area noted above, the most likely control scenarios and their timing.

In principle, emission control strategies could be developed for each of the areas referred to above in terms of control options. However, our approach is to focus on areas in which emission controls are realistic policy options. This reflects a judgment about the technical and economic parameters involved in different areas and these parameters are discussed in the report.

Exhibit II-1
CFC, MCF, CTC and halons control options analysis[1]

Process Group	Product Group	Control Options	Emission Controls
Refrigeration and Air Conditioning	Commercial, Residential and Mobile	Alternative refrigerants in new units (HFC-134a, HCFC-123). Recycling program for old units and service applications. Alternative leak test gas. Require isolation valving. High pressure centrifugal chiller; HCFC-22.	Important area to develop. Service codes may be required.
Flexible Foams	Slabstock and Moulded	Alternative blowing agents; Methlene Chloride blends, HCFC-123, HCFC-141b. Product substitutes. Modified polyol systems. Emission controls (open cell makes this more attractive). Fibrefil alternatives; alternative foams. Minimum foam density for CFC use. Firmer automotive seats.	Feasible, but unlikely to be cost-effective.
Rigid Foams	Polyurethane Foam Bunstock and Laminated Boardstock	Alternative blowing agents, especially for new plants; HCFC - 123, HCFC-141b. New polyols. Fibreglass promotion.	Limited applicability with closed cell foams.
	Polyurethane Poured and Sprayed	Alternative blowing agents; HCFC-123, HCFC-141b, blends.	Applications are in place making emission controls very expensive.
	Polystyrene Foam Boardstock	Alternative blowing agents (142b), including HCFC-22 blend or substitution. Emission controls (closed cell). Fibreglass promotion.	Closed cell.
	Polystyrene Foam Sheet	HCFC-22 requirement.	
	Phenolic Foam	Alternative blowing agents. Substitute products.	Closed cell.

Exhibit II-1
CFC, MCF, CTC and halons control options analysis (continued)

Process Group	Product Group	Control Options	Emission Controls
Sterilants	Sterilants	Contract out. Alternative gas. Disposable instruments. Radiation cleaning. Ban with medical exemption.	Initiatives in hospitals likely to require government support.
Solvents	Solvents	Freon SMT.[2] Aqueous cleaning. Product alternatives (health hazards). Low solid fluxes.	Tighter cleaning systems.
Halons	Portable Extinguishers-1211	CO^2. FE-25.[3] Reduce Training Emissions. Dry chemical.	Potential to work with fire protection organizations.
	Fire Protection Systems-1301	CO^2. FE-25. Water. Alternative Leak Test Gas.	Range of controls being implemented.
Methyl Chloroform	Solvent	Product alternatives. Water.	As in solvents.
Carbon Tetrachloride	Pesticides, solvent	Few uses except as a feedstock.	Limited emissive uses.

[1]This is an exhaustive list which includes some product groups which do not currently exist in British Columbia. These are elaborated on in Chapter III where appropriate.

[2]Freon SMT is a DuPont tradename for a 113 solvent that is blended to reduce the ODP and GWP.

[3]FE-25 is a DuPont tradename for CF_3CHF_2, a replacement for halon, that is currently under test and has an ODP value of 0.

III

Control Options

A. Overview

For CFCs, halons, MCF and CTC, control options are the policies or alternatives that will be pursued as part of a strategy of reducing and phasing out these substances. The alternatives being pursued and the timing of the various transitions are clearly important in developing effective policies in British Columbia.

The following sections of this chapter review control options for the following:

- Refrigeration and air conditioning.
- Flexible foams.
- Rigid foams.
- Sterilant gas.
- Solvents.
- Halons.
- Methyl chloroform.
- Carbon tetrachloride.
- HCFCs (review of uses only).

We recognize that not all of the products discussed in this section are produced in British Columbia. We include in our review a description of these products if there are significant uses in British Columbia.

Although the control options are roughly prioritized in this chapter, it is difficult to rank them because of the implicit constraints. These include:

- Technical—e.g., requirement for equipment redesign.
- Regulatory—e.g., some of the HCFC's are not yet approved.

- Economic—e.g., the cost of switching to alternatives may be high.
- Socio-political—e.g., the balance of desired reductions versus imposed economic hardship on industry.

In general, however, the first priority is to reduce consumption. This can be achieved either by decreasing total demand or, where this is not possible, by switching to alternate products or systems that result in reduced emissions. Further, it is important to look at the full cradle to grave assessment of alternatives. For example, industry and government will have to decide whether it is better to have emissions of HCFCs and a resulting "minor" impact on the ozone layer and greenhouse effect, versus an alternative that may have ODP and GWP values of 0, but is a known carcinogen in small quantities. It is beyond the scope of this study to make such recommendations.

The next priority is to reuse. All users should be prompted to reuse substances where possible.

The third priority is recycling. A growing market exists for recycling machines for CFC-12 extracted from refrigeration and air conditioning installations, for example. The machines start at about $5,000 and can remove condensation and other common impurities. For heavily contaminated substances, such as cleaning solvents, more elaborate equipment is required at a central facility.

The recycling infrastructure is gaining momentum as substance prices rise due to decreasing availability. Manufacturers, such as DuPont, are investing in the capital equipment for recycling which is required to maintain a pool of substance that will be needed well into the next century to service existing installations.

Commensurate with the 3R's (reduce, reuse and recycle), training and education, particularly for the service sector, is essential. The trades must be fully versed in the need for reducing emissions and the appropriate options that can be employed. Training should consequently be an integral part of any and all options pursued. Consideration should also be given to public information programs.

B. Refrigeration and air conditioning

The refrigeration/air conditioning group accounts for nearly 45% of Canada's yearly CFC consumption compared to 75% in British Columbia. In addition, there are substantial quantities of HCFC-22 used in this sector. The major sectors are:

- Commercial refrigeration and air conditioning.
- Residential refrigeration and air conditioning.
- Mobile air conditioning.

The major control options are:

- Alternative refrigerants in new units.
- Alternative leak test gas.
- Isolation valves.
- High pressure centrifugal chillers (HCFC-22).

1. Commercial refrigeration and air conditioning

The prime CFCs used in commercial refrigeration and air conditioning are:

- CFC-11 (ODP = 1.0, GWP = 0.34).
- CFC-12 (ODP = 1.0, GWP = 1.0).
- CFC-115 (ODP = 0.6, GWP = 2.8)—as part of R-502.

The control options to reduce CFC use are:

- Alternate refrigerants in new units.
- Recycling programs for existing units and service applications.
- Alternative leak test gas.
- Isolation valves.
- High pressure centrifugal chillers (HCFC-22).

The industry is working closely with suppliers in the development and testing of two alternate refrigerants:

- HCFC-123 (ODP = 0.03, GWP = 0.0064) to replace CFC-11.
- HFC-134a (ODP = 0.00) to replace CFC-12.

Once these refrigerants have passed all required tests, it is expected that industry will switch over to these new products within a short period of time. In the meantime, industry whenever technically and economically possible, is switching new units to HCFC-22 (ODP = 0.05, GWP = 0.098) and R-502 (ODP = 0.33, GWP = 1.1). Units using HCFC-22 are being used for these conditions:

- Less than 1,000 ton refrigeration capacity.
- Minus 10°C and up at the evaporator inlet.

For higher capacities and temperatures down to -40°C, R-502 units can be used.

CFC and HCFC recovery and recycling programs should and will be further developed. The recovery of gases during servicing and at decommissioning is on the increase and will gain momentum as the prices for these substances increase. Likewise, recycling will become a strategy of increasing importance as availability decreases.

Based on industry practices today, the prohibition of leak testing using CFCs is quite feasible. At the factory, a two stage ban could be implemented:

- Stage 1: Allow only HCFC-22 or helium.
- Stage 2: Allow only helium.

For testing of field installations, contractor personnel today use either HCFC-22 or nitrogen. So, again a CFC ban for that application should present no undue hardship.

Isolation valves are an extra cost but can certainly be incorporated in new designs. However, commonality with U.S. product design is an issue.

High pressure centrifugal chillers using HCFC-22 as a refrigerant are commercially available up to a capacity of 1,000 tons of refrigeration. The penalty is a 5 to 7% increase in power consumption and possibly more costly control systems.

2. Residential refrigeration and air conditioning

The key issue in the residential sector is the use of CFC-12 in home refrigerators and freezers. Residential air conditioners and heat pumps use HCFC-22.

The long-term solution to the CFC-12 issue is its replacement by HFC-134a in new units once this product passes all required tests. In the meantime, industry is reluctant to switch to either HCFC-22 or R-502 for new units for both technical and economic reasons. Given the high degree of commonality between Canadian and U.S. appliances, a combined North American approach is required in the residential field.

As with industrial/commercial units, helium based leak testing at the factory could be made mandatory. Isolation valves are quite feasible in new designs. If this enhancement is mandated, all competitors will be placed on the same footing.

3. Mobile air conditioners

CFC-12 is used in mobile air conditioners. Car manufacturers feel that the introduction of HFC-134a is close enough that it does not pay to experiment with HCFC-22 or R-502. The transition to HFC-134a in mobile applications is expected to be completed by 1995.

C. Flexible foams

Flexible polyurethane foam is produced as slabstock in a continuous process and as individually molded products. The foam is generated from the chemical reaction of a polyol, isocyanate and water. The reaction of the water and the isocyanate creates carbon dioxide, which is the primary blowing agent in the foam production process. For foams with low densities or more softness, an auxiliary blowing agent is used. This is generally methylene chloride, CFC-11 or a mixture. As well as affecting foam characteristics, the auxiliary blowing agent dissipates some of the heat resulting from the isocyanate-water reaction.

Estimates by Peat Marwick Stevenson & Kellogg indicate that total annual usage of CFC-11 in this application in Canada during 1990 was approximately 1.0 kT. This is a 39% reduction from the estimated 1986 baseline total of 1.65 kT. Most of the reduction (0.45 kT) is attributable to the transition of producers of molded products to systems that are completely water-blown. However, some of the reduction (0.2 kT) comes from the slabstock sector where most producers have reduced the usage of CFC-11 per unit of output. The extent to which methylene chloride proportions can be increased is limited, however, because the strong solvent action of this substance alone prevents the production of an acceptable product.

Most flexible foams (approximately 75%) produced in Canada do not require the use of an auxiliary blowing agent—that is, they are made without CFCs. An auxiliary blowing agent is required for high density soft foams and for low density foams. These products account for 7 1/2% and 17 1/2% respectively of Canadian slabstock production.

Flexible foam products are used in a variety of applications but the furniture sector is the dominant market for slabstock. Molded flexible foam is used extensively in transportation applications but most molded foams no longer use an auxiliary blowing agent.

To date, industry control strategies to reduce CFC use have included:

- Switch to water-blowing for molded products.
- Use of more water for soft and low density foams.
- Reducing the proportion of CFC-11 in the mix of the standard auxiliary blowing agents (CFC-11 and methylene chloride).
- Reducing toluene diisocyanate (TDI) indexes which reduces hard segments and peak core temperatures and requires less auxiliary blowing agent.

Flexible foam producers and manufacturers of their raw materials are also pursuing changes in the chemicals used to allow production of low density foam and softer high density foams without an auxiliary blowing agent. If these development efforts are

completely successful, approximately 50% of flexible foams now using an auxiliary blowing agent could be blown without CFC-11 and also without the new chemical substitutes. In the case that both modified chemical technologies and chemical substitutes for CFC-11 are available, producers would presumably choose between them on the basis of their relative costs and processability for making the foam grades for which they are required.

The major research thrust in chemical modification technologies is aimed at the 17 1/2% of the market in which CFC-11 is now used to produce low density foams. In producing this product, CFC-11 is now used because the interaction of water and isocyanate alone generates more heat than currently available polymers can withstand. The modified polyols that are being developed will tolerate more heat and, as a result, more water can be used. As indicated above, if the polyols are modified sufficiently, a significant proportion of the lowest density foams could be blown with just the carbon dioxide generated by the water-isocyanate reaction. Commercial systems of this kind are expected to be available by 1993.

A separate program is being carried out by chemical suppliers for the 7 1/2% market segment occupied by soft high density foam. This research focuses on modified polyols referred to as heteropolyols. Products of this type are now commercially available. The initial price premium on such products may be as much as 40%.

The dominant control option strategies in this industry are:

- HCFC-123 and/or HCFC-141b will be used to replace CFC-11 when they become commercially available in 1994.
- New polyols and new systems will increase their market share particularly for high density soft foams.

D. Rigid foams

1. Overview

Rigid foams are used in a wide variety of insulation applications in Canada. Their use has expanded rapidly in the past 25 years largely due to the favourable economics of insulating with a low density foam. The major market segments are:

- Polyurethane foam.
- Polystyrene foam.
- Phenolic foam.

Data from Environment Canada indicate that 6.9 kilotonnes of CFC-11, CFC-12 and CFC-113 were consumed to produce the 1987 quantity of rigid foam. This total has declined significantly since that time. Insulation applications dominate these totals

although CFC-12 was used to produce polystyrene foam sheet for food service applications until the end of 1988. The remainder of this chapter outlines the potential control options for each of these market segments.

2. Polyurethane foam

Rigid polyurethane foam is produced as the result of a reaction between polyol and an isocyanate. This reaction takes place together with catalysts, usually a fluorocarbon blowing agent and, in some cases, water. The reaction of the polyol and the isocyanate generates heat which vaporizes the CFC blowing agent. In this reaction, anywhere between 80% and 97% of the gas—CFC or carbon dioxide—is retained as bubbles in the expanding polyurethane foam. The superior insulating properties of polyurethane depend critically on the CFC being trapped in the closed cell structure.

The CFCs used in the production of rigid polyurethane foam are CFC-11 and CFC-12. In the production of bunstock and boardstock, CFC-11 is used exclusively while in various poured and sprayed applications, some CFC-12 for frothing is also used. CFC-11 is still the dominant blowing agent in this segment. In insulating applications, the low conductivity of the CFC-11 trapped in the closed cell structure of the rigid polyurethane is the major source of its superior insulating properties.

Control options, particularly in the short term, are somewhat limited in the case of rigid polyurethane foam. These options consist of:

- Emission controls.
- Chemical and process substitutes.

a) Chemical substitutes

The rigid polyurethane foam industry and current CFC suppliers regard HCFC-123 and HCFC-141b as the most likely substitutes for the use of CFC-11. The CFC-12 that is used primarily for frothing may be replaced by HCFC-22 or HFC-134a. A joint testing program is currently in progress to assess how HCFC-123 and HCFC-141b can be introduced as substitutes. This program is a joint effort of the Society of the Plastics Industry of Canada and the National Research Council.

Research to date indicates that both HCFC-123 and HCFC-141b are strong candidates as a substitute for CFC-11. However, rigid polyurethane foam is not a single product but a range of products with different properties and different requirements depending on the location and purpose of the application. As a result, new blowing agents may differ across applications and in some cases, the use of a mixture of blowing agents may be necessary.

In addition to new blowing agents, systems suppliers are developing new polyols. The long run objective of these systems is to produce foams that do not require CFCs or HCFCs.

b) Product substitutes

A variety of insulation products compete in the marketplace with R-value per dollar as the primary factor influencing sales. Fibreglass is the principal alternative to CFC-blow rigid foams but in many applications, costly design changes would be required. In many poured and sprayed applications, there simply are no suitable alternative materials. In principle, the surfaces to be insulated could be redesigned to allow the use of alternative insulating materials but this would be extremely costly.

3. Extruded polystyrene foam

Extruded polystyrene foam is produced in Canada as boardstock for a variety of insulating applications and as foam sheet used primarily in the food service industry. Both products are made from a polystyrene resin which is melted and into which a blowing agent is injected prior to extrusion. As this mixture leaves the extruder, the CFC-12 volatilizes to create the foamed plastic.

Polystyrene foam boardstock is a closed cell product and the trapped CFC-12 is responsible for the current R-values of these boards. Alternative blowing agents like HCFC-22 produce boards with good structural qualities but with much reduced R-values.

Polystyrene foam sheets are used in food packaging applications to produce disposable food containers, cups, egg cartons, plates and bowls. The production process for foam sheet is similar to that described above for boards except that these products are thinner and more flexible. CFCs have been replaced in this application with HCFC-22.

The major control options for reducing the use of CFCs in this product group are:

- Alternative insulating materials.
- Chemical substitutes.

a) Alternative insulating materials

In the present market context, the major competitors of polystyrene boards are other CFC-blown products. This competitive situation reflects the advantages that these products have over other product substitutes. However, there are available substitutes, particularly fibreglass in many applications.

In considering product substitutes, the cost of building redesign must be taken into account and these costs will be substantial in some cases. The major disadvantage of most product substitutes is much lower moisture resistance that makes them quite unsuitable in some applications.

b) Chemical substitutes

The production of polystyrene boards using alternative blowing agents is more advanced than in the case of other rigid foams. In the other market segments, chemical alternatives will not be available until 1992 or 1993 when toxicity testing is completed for HCFC-123 and HCFC-141b.

The major Canadian producer of polystyrene boards is Dow Chemical which accounts for more than 80% of the market. Dow has already replaced CFC-12 as a blowing agent with a substitute that has an ODP of 0.05 or less.

The use of HCFC-142b and blends with an ODP of 0.05 is viewed as a bridging approach in polystyrene boards. The preferred long-run solution is to switch to HFC-134a. This substitute has an ODP of 0 and does not have the flammability problems of HCFC-142b. The availability of HFC-134a is scheduled for 1992.

In this industry segment, the switch to chemical substitutes has dominated other control options. Very substantial ODP reductions have occurred.

4. Phenolic foam

There are no known phenolic foam manufacturers in British Columbia. This information is provided in the event that phenolic foam manufacturing is initiated in the province. Two control options are discussed in the section that follows. They are:

- Alternative insulating products.
- Chemical substitutes.

a) Alternative insulating products

For closed-cell phenolic foam, other CFC-blown rigid foams are the current competitors. In many of these applications, the use of substitutes like fibreglass is feasible. However, the costs may be substantial in the form of both increased energy costs and design changes. Polystyrene boards blown with HCFC-142b with an ODP of 0.05 may be able to increase their market share.

b) Chemical substitutes

The phenolic foam industry requires the development of a chemical alternative to CFC-11 for closed cell boards. The trapped gas must have a low thermal conductivity to maintain the favourable R-value per inch characteristics of phenolic boardstock.

The two alternative gases that are being tested for phenolic boards are HCFC-123 and HCFC-141b, both of which are expected to be available in 1993. HCFC-123 has been used in pilot tests and appears to have advantages over HCFC-141b, which is flammable, requiring costs to explosion-proof plants. In processes where CFC-114 is used, a mixture with as much as 50% HCFC-142b may be used as an interim blowing agent.

E. Sterilant gas

CFC-12 is used as a diluent with ethylene oxide (EO) to produce the sterilant gas used by hospitals and commercial sterilizers in Canada. The purpose of the CFC-12 is to reduce the flammability of EO which constitutes only 12% of the mixture in contrast to CFC-12 which makes up the remaining 88%. This mixture, known as 12/88, is widely used in Canada and most of the gas is released to the environment at the end of the sterilization cycle.

Steam sterilization is a common alternative to the use of sterilant gas. However, many of the newer and more sophisticated medical devices are made of polyvinylchloride or polyethylene components that will melt or deform at the high temperatures of steam sterilization. It is possible to sterilize medical devices using pure EO but the flammability and explosive properties of this gas in a non-diluted form mean that this option is very unlikely to be used in large hospital sterilizing units.

The significant reductions that are occurring in CFC use in this sector come in large part from changes in conservation practices. As well, some large contract sterilizers are committed to eliminating their use of CFCs and this contributes to the negative trend. However, the overwhelming majority of 12/88 gas is used in hospitals in British Columbia and we estimate that most of these hospitals will continue to use substantial quantities. Some smaller hospitals have switched to small table top sterilizers using pure EO but flammability concerns will likely preclude the use of pure EO in larger units.

For the intermediate term, solutions in this sector fall into three categories:

- Recycling units that will allow recovery of 70-100% of the CFC-12 used in the sterilization process.
- The development of HCFC diluents.
- Sterilization in other ways without the use of CFCs and more use of disposable devices.

In the latter category, a sterilant gas known as 10/90 that is 10% EO and 90% nitrogen is widely available. Although it provides an immediate solution and is being adopted by some large contract sterilizers, this is unlikely to be adopted widely in Canadian hospitals. Concerns about flammability and explosions are paramount here but the large capital costs that would be required are also a concern.

In the case of 12/88 sterilant gas, it is very difficult to determine what the most likely pattern of adjustment away from CFCs will be. The fundamental difficulty here is in predicting what policies hospitals in British Columbia are likely to introduce with regard to CFC use. The difficulty rests on the fact that hospital policies will be determined in large part by the funding decisions of the provincial government. In particular, the widespread purchase and installation of recycling units by hospitals could contribute to sharply reduced consumption.

The preceding paragraphs indicate that most of the 12/88 sterilant gas problem in British Columbia is associated with provincially-operated hospitals. These hospitals are generally funded through separate capital and operating budgets. As a result, the economic pressures that are forcing adjustments in other using sectors may work less effectively in this sector. More direct measures may be required to encourage a rapid phase-out of CFC use. This raises the possibility that the British Columbia Ministry of Environment may be able to work cooperatively with the hospitals and the major sterilant gas and sterilization system producers to establish a schedule for investing in recycling equipment and rapidly phasing out the use of CFC-12. The alternative is to wait for the new HCFC products and not focus on recycling until the Montreal Protocol is ultimately amended to include HCFCs.

Substitute sterilization processes that would not involve the use of EO consist of the following:

- Radiation.
- Steam.
- Formaldehyde/steam.
- New technologies including peracetic acid, chlorine dioxide, ozone or hydrogen peroxide.

As noted above, steam sterilization is effective for many medical devices that are often sterilized using 12/88 and increased use of steam in hospitals is likely to contribute to the continuing reduction in the use of CFC-12. However, for a variety of reasons, radiation, formaldehyde/steam and the various new technologies are unlikely to contribute substantially to reductions in CFC use before 1995.

F. Solvents

Chlorofluorocarbon solvents were developed during the 1950s to clean manufactured parts, particularly in the aerospace and electronics industries. These solvents are presently used in the cleaning of most electronics and computer-related equipment, as well as in cleaning various medical and pharmaceutical products. The chemical used is CFC-113 and its advantages relate to its high degree of purity and its compatibility with the materials being cleaned, especially plastics and polyvinyls.

Solvent cleaning using CFC-113 is carried out using a number of different processes. The cleaning processes are:

- Conveyorized vapour degreasing.
- Cold cleaning.
- Dry cleaning.
- Open top vapour degreasing.

The major approaches to CFC elimination that are being pursued in this sector are:

- Improved recycling and conservation practices.
- Reduce or eliminate cleaning requirements.
- Aqueous cleaning.
- New HCFC solvents.
- Not in kind substitutes such as hydrocarbons and terpenes.

Some large users in the electronics sector are introducing process changes in the form of no clean fluxes. This type of process change is expensive and is unlikely to be pursued in the smaller firm sector until an off the shelf substitute is available that is applicable to their process.

Many approaches to water washing are being developed. One concern with the use of water is oxidization and there are a variety of approaches being developed. One manufacturer of micro-computers has reported a water washing method that is carried out within a centrifuge from which the oxygen has been purged.

From SMT, a DuPont tradename for a CFC-113, methanol and trans-1,2 dichloroethylene blend, is a transitional product with an ODP value of 0.55 (GWP is unknown). It will likely be replaced by a full HCFC product in three to five years.

In the area of HCFC substitutes, the leading candidates are HCFC-141b, a blend of HCFC-141b/123 and HCFC-225. The HCFC-141b and HCFC-123 solvents are closer to commercialization (expected during 1993 or early 1994) than HCFC-225, but involve equipment changes that would be substantially more costly than for HCFC-225. The new HCFC-225 solvents would be close to a drop-in replacement involving no equipment changes or only minimal changes. Those small users for whom the conversion cost factor is most important are the ones that are likely to prefer to wait for the availability of a drop-in.

Alternative hydrocarbon-based solvents are now commercially available but do not work equally well in all processes and require substantial investments in process changes. Among the solvent cleaning alternatives, this is the farthest away from being a drop-in substitute.

A major constraint on the reduction rate of the use of CFC-113 in the solvent sector is the application of military specifications (MILSPEC). These specifications dictate that for use in military applications, components must be cleaned with CFC-113 and that recycled material may not be used. Many contracts require cleaning in this way rather than to a performance standard that might be met in some other way. As a result, changes in MILSPEC will play an important role in determining the rate at which the consumption of CFC-113 is cut.

The MILSPEC problem does not affect the entire electronics sector. Commercial electronics like telephone equipment and computer circuit boards generally do not face MILSPEC. It is for this reason that we expect most major non-MILSPEC users of CFC-113 to eliminate their consumption by the end of 1992. We understand that the issue of MILSPEC standards is under review and that changes in the standard are anticipated that would produce alternative cleaning standards. Any delays in these changes will make the elimination of CFC-113 more difficult.

G. Halons

Halon has been used widely in portable fire extinguishers and in total flooding fire protection systems. In general, Halon 1211 with an ozone depletion potential (ODP) of 3 is used in portables and Halon 1301 with an ODP of 10 is used in total flooding systems. Sales of halon 1301 systems have declined sharply during 1990 and 1991. Higher prices for halon may have played a small role but customer aversion to installing systems with ozone depletion properties seems to be the major factor.

The rapid growth during the 1970s and 1980s in the use of halon relative to other agents is explained by its desirable properties as a fire-fighting agent. These properties include:

- Cleanliness of halon as an agent in reducing damage costs and clean-up costs.
- Relatively low toxicity, particularly in the case of 1301.
- Non-conductivity making it desirable for electrical fires and around electrical connections.
- Higher permeability as a gas in reaching fires, compared to direct sprays.

Under proposed regulations by Environment Canada, the use of halons in portable fire extinguishers will be prohibited with the exception of certain essential uses, primarily in aircraft. As a result, the remainder of this section focuses only on total flooding systems.

Halon 1301 is used in total flooding systems designed to protect computer rooms, tape libraries, telephone exchanges, and valuable historic artifacts—applications where valuable property must be protected and other agents are unacceptable. Most Halon 1301 that is produced is "banked" in fire protection systems. At the present, alternative agents with comparable properties do not exist and the timetable for substitutes with substantially the same properties extends much farther into the future than is the case with CFCs. For this reason, control options focus on directing Halon 1301 systems to areas where different fire extinguishing methods are inappropriate and on reducing non-fire emissions as much as possible.

For Halon 1301, the most important options include the following:

- Development of "in cabinet" systems.
- Improved discharge test procedures.
- System leak detection devices.
- Use of Halon 1211 systems in unmanned areas.
- Use of Halon 1211/1301 blends.
- Reduction of unwanted discharges.

1. Use of Halon 1211 systems

The major differences between Halon 1211 and Halon 1301 relate to their ODP levels and their toxicity. Although Halon 1211 has a lower ODP, it is toxic at the concentration required to put out fires. As a result it can only be used in areas that are not normally occupied. This is an area that fire protection firms are pursuing actively now. The lower ODP of Halon 1211 systems allows them to sell roughly three times more of such systems relative to Halon 1301 systems under the quantity restriction of the Montreal Protocol.

2. In cabinet systems

Halon 1301 systems are used to protect electronic equipment because the agent is not destructive of the protected equipment and it is not toxic at the concentrations required to extinguish fires. Typical Halon 1301 systems protect the rooms that house computer equipment. These systems generally require one pound of halons to protect every 50 cubic feet of enclosed space. (EPA, *Halons*, p. 3-10.)

To the extent that computer equipment can be segregated and housed in smaller compartmentalized spaces, smaller fire protection systems using less halon can be installed. These are referred to as "in cabinet" systems and these are being developed by systems manufacturers. Surrounding premises would be protected by non-halon systems.

A further advantage of smaller enclosed areas is that some would be "unmanned." In such areas, Halon 1211 with its lower ODP can be used.

3. Blends of Halon 1211 and Halon 1301

The rationale for such blends is the same as for the use of Halon 1211 systems. A lower combined ODP allows the production of more systems. A blend makes the gas less toxic as the proportion of Halon 1301 increases. Both halons extinguish fires at 5% concentrations, but Halon 1211 is toxic at this level whereas Halon 1301 becomes toxic only at 10% concentrations. A 50:50 blend would be toxic at 7 1/2% concentrations and could be used to put out fires. The negative aspect of this option is that the margin for error with regard to toxicity is reduced as the proportion of 1211 increases.

4. Substitute chemicals

The major producers are working on substitutes for Halon 1301 with very low or zero ODP. Products are now being tested (e.g., FE-25, a DuPont tradename for CF_3CHF_2) but these alternatives are not expected to be commercially available until 1995.

Dry chemicals and CO_2 can be used in certain applications as a replacement for Halon 1211 and 1301. However, in some applications these alternates have "undesirable" effects that are not found with halon (e.g., corrosiveness).

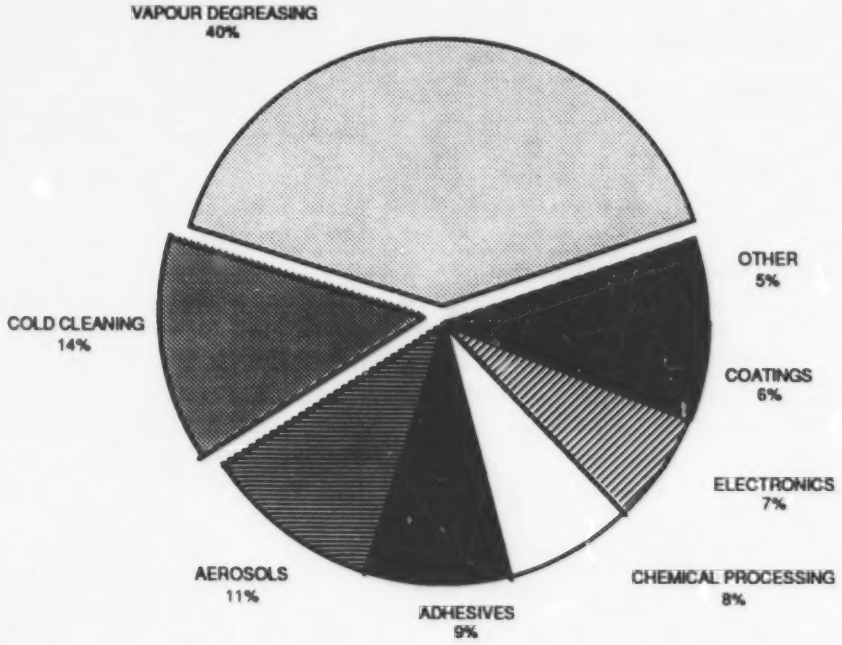
H. Methyl chloroform

Methyl chloroform (MCF) is used widely as a solvent and has replaced other solvents that do not share its low toxicity and low flammability properties. Some alternatives to MCF are subject to increasing regulation as volatile organic compounds (VOCs) making its replacement more difficult.

The distribution of MCF consumption for Canada in 1989 is shown in Exhibit III-1. Nearly 55% of MCF is used in cleaning applications either in vapour degreasers or cold cleaning units. The other major uses are as a solvent in some aerosol applications and in some adhesives. The MCF fraction of total aerosols and total adhesives is small. It is used in these applications where alternative solvents have performance difficulties. This makes the cost of replacing it high.

The range of applications of MCF crosses a variety of industries including electronics, automotive, metal fabrication, machine parts, medical products, aerosols, coatings and adhesives. As a result of the extensive industrial list of applications, the uses of MCF are usually described in the categories shown in Exhibit III-1. We assess the most important of these areas and possible control options in the following paragraphs.

Exhibit III-1
Methyl chloroform consumption in Canada (1989: 14.5 KT)



Source: Dow Chemical

Vapour degreasing with 40% of Canadian consumption is the largest use category for MCF. There are a variety of vapour degreasing technologies available including vapour exposure alone, vapour and spray and immersion-vapour cleaning. MCF provides a high standard of cleanliness and a dry part that is ready for further processing. Solvent is emitted in vapour degreasing as a result of:

- Solvent loss when cleaned piece is removed from degreaser.
- Losses when dirty solvent is replaced.
- Leaks and other exhaust emissions from the degreaser.

Control options for vapour degreasing include:

- Tighter equipment to reduce short run emissions with emissionless "bubble cleaning" in the longer run.
- Other chlorinated solvents (methylene chloride and others).
- Aqueous and semi-aqueous systems.
- Terpenes.
- HCFC solvents.

Some of these options for vapour degreasing can be introduced quickly. Conservation may have the potential to reduce MCF consumption by 25% from 1989 levels or more although many users have already changed their practices. The EPA studies of MCF suggest that aqueous cleaning will play a large role in ultimate replacement. These new aqueous systems will be used for cleaning applications to which they have not yet been applied extensively. Aqueous technology continues to develop and industry sources indicate that by 2000, these systems will more readily substitute for MCF. In some cases, conversions are now possible to aqueous cleaning but the costs can be substantially higher than for MCF. In general, firms that now use MCF in preference to aqueous do so because of a combination of technical cleaning advantages and cost advantages for MCF.

Cold cleaning is another metal cleaning application of MCF. As the name indicates, the solvent is used at room temperature instead of being heated as in the case of vapour degreasing. The range of cold cleaning applications is extensive and includes immersion cleaning, spraying and wiping. Evaporation and drag-out losses are the primary sources of emissions in cold cleaning. Some of these losses can be reduced through conservation practices but the nature of this type of cleaning limits these reductions.

In the case of cold cleaning, control options include:

- Conservation practices, lids, closing equipment.
- Other chlorinated and non-chlorinated solvents.
- Aqueous systems.
- Hydrocarbons, alcohol.

The wide range of cold cleaning applications makes generalization difficult about the alternatives that will be adopted. Other solvents such as hydrocarbons and alcohol solvents exist and are presently used in competition with MCF. Current uses of MCF reflect concerns about safety or cleaning capacity since MCF solvents are more expensive than these alternatives.

Adhesives constitute 9% of Canadian consumption of MCF. However, adhesives using MCF as a solvent constitute only 2-3% of the total Canadian market for adhesives. MCF is used as a solvent in these applications because of the following concerns about alternatives:

- Organic solvents can be used in some applications but have seen reduced market shares primarily as a result of flammability and occupational health and safety concerns.
- Water-based adhesives are widely used due to their lower costs and absence of toxicity problems. In some applications, however, water-based adhesives have performance problems associated, for example, with the promotion of rust in metallic applications or mildew in furniture.
- Hot melts are possible in some applications but performance as an adhesive can be a problem.

Research is underway in Canada and among adhesive producers elsewhere to develop alternatives to MCF. In some current adhesive applications, substitutes for MCF are being introduced but the wide range of applications and performance requirements means that there is not a single solution. Some specific substitutions may involve development costs of $50,000 to $100,000 and adhesive manufacturers could have as many as 200 MCF product lines although each substitution would not involve this much cost.

The electronics sector uses MCF as a solvent and accounts for 7% of consumption. Applications include cleaning circuit boards, automotive electronics components and a variety of electronic parts and instruments. Some current MCF users in this sector may have switched to MCF from CFC-113 due to the regulation of 113 under the Montreal Protocol.

Control options in this application are similar to the alternatives for CFC-113. These include:

- Reduced cleaning, no clean solder fluxes.
- Terpenes.
- HCFC solvents.
- Aqueous, semi-aqueous.

For a number of reasons including early pressure from the initial Montreal Protocol, alternatives to MCF in electronics appear less costly than in the sectors discussed above.

The overall picture for MCF is that various control options exist but the costs, particularly in the short-run are high for many options. Reductions in the use of MCF are feasible and are occurring in some areas but complete elimination at an early date appears quite costly.

I. Carbon tetrachloride

Most of the carbon tetrachloride that is produced in Canada is non-emissively consumed as a feedstock in the production of CFCs. In Canada, carbon tetrachloride is used in the following applications:

- To prevent the accumulation of explosive quantities of nitrogen trichloride in the production of chloride.
- As a catalyst promoter in oil refining.
- In certain laboratory and testing users where carbon tetrachloride is used as an extraction medium.

It is our understanding that there are alternative procedures for the first two applications and that producers will ultimately adopt them to eliminate the use of carbon tetrachloride. There may be no immediate substitute for some laboratory uses, but the quantities in this category should be very small.

J. Hydrochlorofluorocarbons (HCFCS)

The use of HCFCs will increase as CFCs are replaced. The revised Montreal Protocol indicates that there should be no new uses of these substances. However, the Parties are not yet considering control options because the HCFCs are viewed as necessary to bring CFC consumption down quickly.

In the previous sections of this report, we indicated where HCFCs were likely to be used. Opinion continues to vary on when policies should be developed to phase out HCFCs. Control options at this point in time would be highly speculative. As a result, we consider the HCFCs in more detail in the next chapter on emissions controls since these can be implemented sooner.

IV

Emission Control Strategies

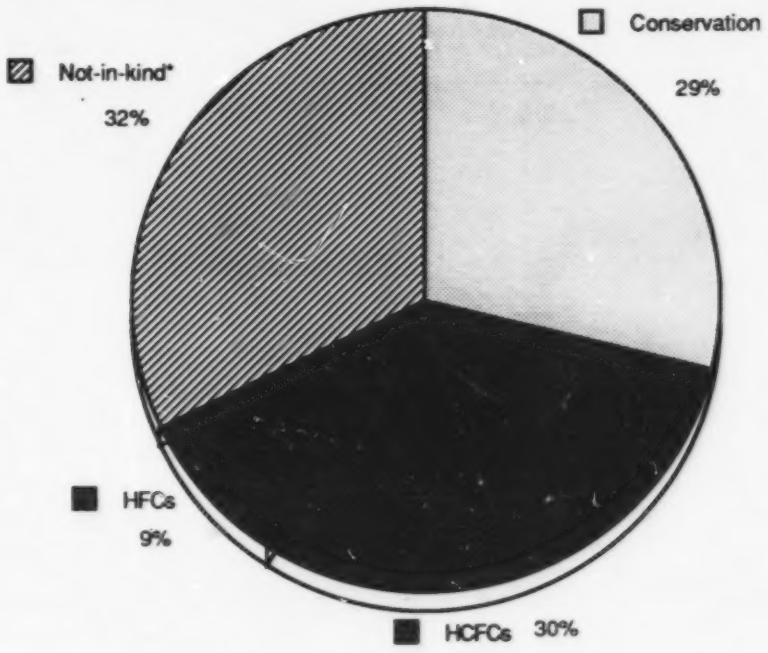
A. Overview

Plans are in place to phase out the use of CFCs in Canada by 1997. Canada also hopes to achieve reduction schedules beyond those required by the Montreal Protocol for all other controlled substances. It is important, however, to focus also on emissions of these substances prior to complete phase-out and to have in place emission control strategies for the HCFCs where they will be introduced as substitutes. The magnitude of the likely role for the HCFCs is shown in Exhibit IV-1. In this regard, emission control strategies are related to control options because in some applications, HCFCs are the immediate control options whereas for others, changes not involving the use of ozone-depleting substances are being introduced.

Emission control strategies are also related to recycling-reclamation of CFCs and halons in particular. Following the phase-out of CFCs in 1997, service demands for existing refrigeration and air conditioning equipment will continue to exist. Reducing emissions, recapturing and recycling must be an essential part of this 1997 phase-out strategy. In the absence of adequate supplies of recycled CFC-11 and CFC-12, the costs of replacing equipment that can no longer be serviced would be very high.

The assessment criteria used in Chapter III are relevant for emission controls as well as for control options. In this project, our interpretation of our mandate is to provide you with information on areas where emission controls would be useful policies for the Province to introduce. We recognize, however, that many factors will determine the policies that are actually selected. As a result, we provide an overview for all sectors, not only those where we think emission controls are feasible. In some cases, this involves providing a description of why such controls are unlikely to be effective in a particular sector. Our assessments in this section involve not only technical feasibility, but also include cost-effectiveness.

Exhibit IV-1
Displacement of today's CFC demand at the year 2000



**Substitutes or alternatives other than HCFCs or HFCs.*

Source: DuPont

B. Refrigeration and air conditioning[1]

Data from Environment Canada show that refrigeration and air conditioning accounted for 44% of total CFC consumption in Canada in 1989. Foam production and solvents were the other major categories. However, the latter applications occur in British Columbia in less than proportionate quantities to population. As a result, refrigeration and air conditioning in British Columbia account for 75% of total CFC consumption. In addition to being quantitatively important, this is an area in which there is a significant potential for emission reductions.

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[1] *This section draws heavily on* CFC Emission Controls, *a report prepared by PMS&K for Environment Canada.*

1. Market segments

In developing emission control policies, different approaches will be required for different market segments. The products by segment are:

Residential:

- Home refrigerators.
- Stand alone freezers.
- Residential de-humidifiers.
- Window air conditioners, central air conditioners and heat pumps.

(All residential window type and central air conditioners and heat pumps use HCFC-22. This refrigerant is not yet controlled by the Montreal Protocol but could be included in emission control policies.)

Commercial/industrial:

- Mid-capacity roof top air conditioning units.
- Centrifugal chillers.
- Refrigerated warehouses.
- Industrial freezers (food processing, medical applications).
- Dehumidification systems.
- Display cases for food stores and restaurants.
- Vending machines.
- Commercial refrigerators (walk-in type).
- Water coolers.
- Ice makers.
- Ice rinks, etc.

The total number of such units in Canada is estimated at 10 million. The quantities of refrigerant carried by these devices is primarily a function of unit capacity. These quantities range from 2 to 300 g for a domestic refrigerator to a tonne for a very large centrifugal chiller installation. The available data indicate that the industrial/

commercial sector accounts for twelve times the CFC usage in the domestic sector. Furthermore, almost 100% of the CFC usage in the commercial/industrial sector is loaded by installation/service contractors. This group therefore represents a key segment of that industry as far as emission control policies concerned.

The major CFCs and HCFCs used in both residential and commercial/industrial applications are:

- CFC-11: Large office tower air conditioning (centrifugal systems)
  Commercial air conditioning systems
  Solvents for flushing refrigeration systems
- CFC-12: Commercial refrigeration (food processing, preservation, storage and display, medical research and storage)
  Small commercial air conditioning systems (roof-top units)
  Dehumidification systems
  Solvents for flushing refrigeration systems
  Home refrigerators and freezers
- CFC-113: Commercial air conditioning systems
  Large office tower air conditioning (centrifugal systems)
- CFC-114: Limited use in large office tower air conditioning (centrifugal systems)
- CFC-115: As a component part of R-502 (R-502 is 51/49 mixture of CFC-115 and HCFC-22)
  Low temperature and commercial refrigeration (mainstay of supermarket equipment)
- HCFC-22: Residential applications, growth in other market segments as a result of the Montreal Protocol.

2. Emission controls

The various types of equipment listed above differ radically depending upon their ultimate application. The approach to CFC emission controls can be classified for all of them under the following headings:

- Design
- Testing

- Installation
- Operation
- Servicing and repair
- CFC recycling and disposal
- Equipment disposal

Each of these elements is discussed below.

a) Design

Equipment using CFCs should be designed to minimize the chances of leakage and maximize the opportunity to collect and extract CFCs safely and economically.

Desired design features for major subsystems are described below.

Compressors

Leaks associated with compressors are generally not related to their design but to the associated equipment fitted on them. Worthwhile design features are listed below:

- Lubrication system:

  Adequate drying and straining in refrigerant system
  Oil filtration
  Containment of oil during shutdowns
  Separate oil pumps
  Double gland seals.

- Vibration

  Solid foundations
  Anti-vibration mountings
  Vibration eliminators in piping and other equipment.

- Adequate isolation of gauges, etc.
- Isolating valves on compressor suction and delivery sides.

Condensers and evaporators

- Anti-vibration mountings.

- Controlled water velocity in heat exchanger tubes.
- Proper water treatment and material selection to prevent corrosion.
- Facilities for flushing on the water side of heat exchangers.

Pipelines and connections

- Minimize number of pipe joints.
- Use brazed or welded connections in preference to flared or screwed connections (this applies to flanges also).
- Prevent vibration stresses.
- Include strainers, filters and driers in the piping system.
- Use nitrogen blankets during welding or brazing to prevent oxidation.

Valves

- Retain leakage through gland and allow tightening/ replacement of gland packing under line pressure.
- Use welded, brazed or flanged connections instead of flared or screwed types.
- Install stop valves to isolate vessels and equipment.

Relief devices

- Use of dual relief valves.
- Adequate safety margins.

Air purgers

(Air purgers are relevant to systems whose suction side operates below atmospheric pressure).

- Frequent operation of the air purger is an indication of some problem area and should be monitored.

Pump down capability

- Design should incorporate a fully protected or isolatable liquid receiver or receiver/condenser of sufficient capacity to hold the complete refrigerant charge.

- The above may involve a separate pump-down condensing unit.

- Fittings and valves to allow the connection of a pump-down unit to remove refrigerant prior to service.

Oil draining

- Refrigerant dissolved in lubricating oil should be allowed to return to the system prior to draining the compressor crank-case. This is done by allowing the oil to sit in the crank case prior to draining and applying gentle heat externally.

At present, all of the above design features are included by manufacturers to varying degrees. The obstacles to their widespread adoption are primarily economic. A set of uniform guidelines agreed to by industry is required to encourage full and uniform application of these principles. If government involvement is required in developing guidelines, a cooperative effort reflecting respective mandates should be pursued.

b) Testing

Subsequent to the Montreal Protocol, industry has discontinued the use of CFC-12 in testing units at the factory. HCFC-22 and preferably helium are being used. Because of the special chambers required for helium testing, the trend is to install helium-based testing facilities for smaller size units and gradually scale up to larger units. A viable approach would be to set target dates for complete testing of units of increasing size using helium.

c) Installation

The major potential for CFC emission at installation is as a result of leak testing and purging and drying of the equipment. For leak testing, the trend is to use a mixture of nitrogen and either HCFC-22 or R-502, in conjunction with a halide detector (freon gun).

In any multiple evacuation of the system, HCFC-22 is used in lieu of CFC-12. But eventually, the HCFC-22 has to be purged out with CFC-11 or CFC-12 if that is the working refrigerant. The collection of purge gas containing CFCs or HCFCs is not the practice today.

d) Operation

The most common indication that an operating system is leaking CFCs is through a noticeable drop in cooling performance. Because of overdesign or low loads, a good deal of CFC may have been lost before a unit can no longer deliver its required refrigeration capacity. Design features such as alarms and appropriate instrumentation and controls can provide:

- warning
- CFC segregation, and
- unit shutdown.

well before a drop in cooling performance becomes noticeable.

The inclusion of "early warning systems" in refrigeration and air conditioning design and regular servicing seem to be the most attractive ways to control emissions during operation. Sensitizing responsible personnel is also an important step.

e) Servicing and Repair

Servicing and repair are key steps in the product life cycle as far as CFC emission controls are concerned. The central actor at this stage is the service contractor and the key issue is the contractor's ability and motivation—both financial and professional—to collect and dispose of used CFCs in an environmentally safe manner.

A number of requirements must be met to achieve maximal collection and safe disposal of used CFCs. Some of these are under the service contractor's control and some are not. These requirements are:

- ▶ Units that feature subsystems for the safe accumulation, isolation and removal of used CFCs.
- ▶ Maintenance personnel who:
  - Are motivated.
  - Are qualified.
  - Have the necessary equipment to remove and store the spent CFCs safely.
- ▶ Transport regulations that do not burden the transfer of used CFCs by road or rail with undue restrictions.
- ▶ A network of qualified recyclers.

- Recognized standards for re-use of recycled CFCs.

- A price mechanism and a set of guidelines/controls to encourage recycling.

At present, these requirements are either in the process of being satisfied or under study.

To simply provide for the removal of CFCs prior to repair or service followed by re-introduction of the same charge following servicing, is not advisable since many repairs are conducted to correct a condition that could lead to CFC contamination. Therefore, removal must be combined with recycling or destruction.

There is an increasing degree of awareness of the need to control CFC emissions in the service community. The Heating Refrigeration and Air Conditioning Institute, an organization with 850 corporate members—not all active in the service field—has been playing a key role in raising this awareness level. This organization has developed courses and a set of guidelines to be followed by industry members. The guidelines are shown in Appendix A. The focus of the Institute is on commercial/ industrial installations. Another organization, the Refrigeration Service Engineers Society of Canada has a membership of 2,700 which covers both domestic and commercial/industrial service personnel. It also provides courses for its members. In British Columbia, the Refrigeration and Air Conditioning Contractors Association (RACCA) provides a similar function at the provincial level.

f) Mobile air conditioning—reclamation and recycling

Substantial quantities of CFC-12 have been vented during servicing of automobile and truck air conditioners. Many service organizations have invested in the new technologies that allow reclamation of used CFCs but problems remain primarily with garages and when vehicles are scrapped. Service codes and, in particular, a requirement for reclamation and recycling would be effective policy responses.

g) Disposal of equipment

A wide variety of air conditioning and refrigeration equipment charged with CFCs will be replaced over the next 20 years. Codes of practice and regulatory policies have the potential to allow recapture and recycling or destruction of this spent refrigeration in the commercial and industrial sector.

Other areas of concern relate to the disposal of of residential refrigerators and freezers and air conditioners in cars and trucks. These are areas in which provincial and local policy initiatives can be introduced. It should be noted, however, that such policies may not be highly cost-effective. Initial charges of

CFC-12 in these units are relatively small. As well, many units will be damaged or broken and may have entirely lost their charge. In the case of residential refrigerators and freezers, the loss of charge may have been the impetus to replace the unit. Some U.S. studies have suggested that the amount of refrigerant left for recovery as used motor vehicles reach junk yards is greater than indicated in earlier studies.

h) Codes of practice

We have noted above the Guidelines of the Heating, Refrigeration and Air Conditioning Institute to reduce CFC emissions. In addition, Environment Canada has published the **Code of Practice for the Reduction of Chlorofluorocarbon Emissions from Refrigeration and Air Conditioning Systems**. Such codes can be developed under the provisions of the Canadian Environmental Protection Act.

The subject areas in the Environment Canada code are:

- Commercial/Industrial Systems

  Design
  Manufacture
  Installation and Servicing
  Usage
  Recovery, Reuse and Disposal of Refrigerants
  Handling and Storage of Refrigerants
  Disposal of Equipment Containing CFCs
  Training of Personnel

- Residential Systems

  Design
  Manufacture
  Installation and Servicing
  Recovery, Reuse and Disposal of Refrigerant
  Disposal of Appliances Containing CFCs
  Training of Personnel

- Mobile Air Conditioners

  Design
  Manufacture
  Servicing
  Disposal of Refrigerants in Automobiles Slated for Wrecking

The codes of practice referred to above are not mandatory although many organizations choose to comply voluntarily. The practices that are set out in these codes do provide useful guidelines as to the types of provincial and local regulations that could be developed.

C. Flexible foam

Slabstock producers are currently considering a wide variety of options to reduce their use of CFC-11 consistent with the implementation schedule for the Montreal Protocol. For a variety of reasons, however, emissions controls to recapture CFC-11 used as a blowing agent do not appear to be a likely option.

The two emission control options available to slabstock producers are:

- Carbon adsorption in a retrofit of existing plants.
- Installation of vertical foam chamber systems in new plants.

A carbon adsorption system is technically feasible for producers of slabstock polyurethane foam but the cost of such systems would be so high that producers are unlikely to choose this option voluntarily. The costs of this form of emission control are related to the production process used for slabstock. The basic characteristics of this process as it relates to emissions controls are described below.

Polyurethane foam slabstock is produced in a continuous process in which the foam is generated from the chemical reaction of toluene diisocyanate (TDI), a polyol and water. The reaction of TDI and water creates carbon dioxide, the primary blowing agent. In some applications, either methylene chloride, CFC-11 or a mixture is used as an auxiliary blowing agent. The effect of the auxiliary blowing agent is to either reduce the density of the foam or to increase the softness of higher density foams. A further important role of the auxiliary blowing agent is to reduce the heat generated by the reaction of TDI and water. The risk of fire in the production process increases as the amount of auxiliary blowing agent is reduced.

For workplace health and safety reasons, the slabstock production process described above requires high speed air movement in the area of the chemical reaction to keep the concentration of isocyanate in the air below 0.05 parts per million. In other words, substantial volumes of air with low chemical concentrations would have to be handled to recover CFC-11 as it is released at the production stage. The low vapour pressure of CFC-11 means that this large volume of air would all have to be chilled to a very low temperature to recover the CFC. These considerations form the basis of our conclusion that such emission controls are feasible, but not economic even for much higher prices of CFC-11.

Industry estimates suggest that approximately 25% of CFC-11 emissions from flexible foam production occur during the production phase. This relatively low percentage

contributes to the low CFC concentrations referred to above. Polyurethane foam slabstock is open cell and, as a result, the remaining 75% of the CFC is released in a relatively short time period after it is produced. A fraction of this total is released when the slabs are cut and most of the remainder is released in the 24 hours after being produced when it is being cured and stored. This release of CFC, although relatively rapid, still implies that very substantial values of air must be handled contributing to the high cost of emission controls.

The alternative production process to the horizontal foam pouring process for polyurethane slabstock described above is a vertical foam chamber. In this process, the slabstock foam rises in a tunnel or chimney as it is produced. Fumes including the CFC-11 that is released during production are trapped in the chimney and therefore concentrations increase. Less air would have to be handled in the recycle process and as a result, the economics may be somewhat more attractive. This production technology is feasible and is used in both Europe and the United States. However, these systems do not now contain devices to capture CFC emissions. These would have to be produced as an add-on. This form of emission control would be expensive and would not recapture a large fraction of the CFC used.

The major drawback of the vertical foam chamber technology is that much smaller output volumes are produced because these production lines work at approximately one tenth the speed of horizontal conveyor lines. In addition, existing plants cannot be converted to vertical foam production through a retrofit. Adoption of this technology would require the construction of a series of new small capacity plants. Collection efficiency from vertical foam chambers may not be much higher than that reported for horizontal lines and conversion costs would be very high.

D. Rigid foams

1. Rigid polyurethane foam

The potential for emission controls for polyurethane foam is limited. It is possible to describe carbon adsorption types of add-on controls as feasible, but only in a very technical sense. At some cost, emission control add-ons could recover some CFC but the quantity would be very small and the cost very high.

The major limitation on the use of emission controls is that very little CFC is emitted during production. The insulating properties of rigid polyurethane foam are based on trapping as much CFC-11 as possible in the closed cell structure of the product. As noted above, the emission rates for the CFCs used is approximately 2 1/2% for laminated boardstock, 5% for bunstock and 15% for poured and sprayed.

For bunstock and boardstock produced in a manufacturing plant, emission controls through carbon adsorption may be described as technically feasible if highly uneconomic. However, for poured and sprayed applications, industry estimates and the published literature suggest that emission controls cannot be described as even

technically feasible. The wide range of applications, many of them on site, means that emission controls do not appear to be a serious option.

2. Polystyrene foam sheet

Extruded polystyrene foam sheet is used in food service applications. This industry now uses HCFC-22 as a blowing agent. As in the case of other products in this category, the product is produced with the intent of trapping the maximum possible quantity of HCFC-22 in the cells to increase its insulating capacity. The result is that very low concentrations are emitted and this makes emission controls very costly per unit of HCFC that can be recovered.

3. Emissions from Banked CFCs

As described throughout this sub-section, the intent of the rigid foam production process is to bank the maximum possible quantity of CFCs in the finished board or product. How feasible is it to recover any of these trapped CFCs at a later date?

Overall, our assessment is that although technically feasible, this is unlikely to be a viable policy option. It would be possible to recover insulation material when older buildings are torn down but the costs of doing this would be extremely high. The used material could then be shredded in a unit designed to capture the remaining CFCs. The quantity of wrecking activity is unlikely to be large enough to sustain an industry of this kind.

E. Sterilant gas

Most of the 12/88 sterilant gas problem in British Columbia is associated with provincially-operated hospitals. These hospitals are generally funded through separate capital and operating budgets. As a result, the economic pressures that are forcing substantial CFC reductions in other sectors may be less effective here. This suggests that there may be a significant potential for the British Columbia Ministry of the Environment to work cooperatively with provincial hospitals and the major sterilant gas producers to establish a schedule for investing in emission control systems for the current 12/88 blend and also for the new HCFC sterilant gases.

In this regard, commercial recycling systems that essentially eliminate CFC emissions are available now. They will be installed throughout California to satisfy environmental regulations in that state. The cost of a CFC recycling unit is approximately $75,000 per hospital. The installation of these systems would lead to significantly reduced expenditures for sterilant gas with one estimate being that the payback period might be in the order of five years.

The barriers to the adoption of these technologies relate to the kind of policies that could be adopted in British Columbia to control emissions. The available evidence suggests that the major potential sources of delay in introducing recycling are:

- Delays in the decision process in provincial hospitals due to uncertainty about or absence of funding.

- Possible regulatory delays associated with the transport of spent sterilant gas to be recycled.

There is a potentially important role for the British Columbia Ministry of the Environment to play with regard to both of these sources of potential delay. Provincial hospitals need to be provided with the information and resources necessary to allow rapid conversion. As well, potential regulatory hurdles are best anticipated and overcome before they act as a barrier in the process.

F. Solvents

Solvent cleaning with CFC-113 continues to constitute a substantial proportion of consumption in Canada-nearly 12% of the total for all CFCs in 1989. In British Columbia in 1990, however, this figure is only 3%. The major pressure currently at work to reduce emissions is the substantially higher price that is being charged for CFC-113. The combination of greater environmental awareness and higher CFC prices has led to the introduction of a variety of industry practices to reduce emissions.

In all areas of solvent cleaning, the long run strategy appears to be to move to tighter cleaning systems. If cleaning can be carried out in a smaller area, then a perimeter vapour barrier can be installed along with vapour recycling equipment. This technology could be effective for CFC-113, the HCFC solvents that are going to be introduced and in a wide variety of other cleaning operations. Most systems of this kind are not yet well-established in North America but any regulatory strategy should begin with this approach as its ultimate objective.

G. Halons

Most of the gains from reducing emissions of halon will come from reduced emissions of halon 1301. This substance is used in total flooding systems in which the quantities used in each system are large. Halon 1211 consumption in Canada is much less than that of halon 1301 and the ODP of 1211 is 3 compared to the ODP of 10 for halon 1301.

An estimate by Taylor/Wagner, fire protection consultants, is that on an ODP-weighted basis, 95% of controllable emissions relate to halon 1301 while only 5% relate to halon 1211. Their data provide the following break-downs for controllable emissions for the two halons:

- 1301 discharge testing (38%).
- 1301 unwanted discharge (24%).
- 1301 filling, R&D, shipping (22%).
- 1301 service (11%).
- All 1211 reductions (5%).

It should be noted that all of these data are based on emissions that were occurring during the mid-1980s. Since that time, a number of changes have been introduced within the fire protection community in terms of how halons are handled. Leak tests have largely been replaced by tests of room integrity, service procedures have been improved as have filling and shipping practices. Portable extinguishers using halon 1211 have been confined by regulation to essential uses and discharge testing and training have been eliminated.

As we point out in more detail in the following chapter, governments and quasi-government organizations at all levels have been major consumers of halon fire protection equipment. This consumption pattern reflects the many useful properties of halon and perceptions of its appropriate role that were formed before its environmental costs were completely understood.

The companion report to this document provides an estimate of halon consumption and the halon bank in British Columbia but the Environment Ministry could take this work farther. Complete documentation of use and inventories by British Columbia government departments and agencies could be established along with emission controls and procedures to handle the halon bank. There are likely so many 1211 portables attached to government walls that a decentralized approach like this is the only feasible method of dealing with the problem.

Our assessment of the evidence suggests that management of the halon bank is an essential part of the process of controlling emissions of halons. A complete inventory for 1301 is a starting point that will allow tracking to ensure that when buildings are renovated or torn down that the halon is removed safely. The intent here should also be the promotion of policies to replace existing halon 1301 systems that are not essential. The benefit of such a policy is that the halon removed from these systems can be used in essential new installations until an environmentally safe substitute is available thereby reducing the need to produce new halon.

H. Methyl chloroform

Methyl chloroform (MCF) is used as an industrial solvent in a wide variety of electronics and other applications primarily in the manufacturing sector of the economy. In some applications, it was adopted as a substitute for CFC-113 before methyl chloroform was added to the Montreal Protocol in June of 1990.

In this light, policies to control emissions of MCF are similar to those discussed for CFC-113. Better conservation practices are being introduced and tighter cleaning systems-bubble cleaning- can act to reduce solvent emission and to promote the replacement of MCF with solvents that can be used safely only if emissions are captured.

I. Carbon tetrachloride

Limited quantities of carbon tetrachloride are used in British Columbia. It has been regulated for some time in terms of acceptable exposure levels under occupational health and safety legislation. As a result, it appears very unlikely that there will be a significant potential for reducing emissions levels farther.

V

Management Options For British Columbia

A. Overview

This chapter sets out the policy implications for British Columbia of the control options review and the assessment of emission control strategies. In it, we provide an outline of how the British Columbia Ministry of the Environment can contribute most effectively to emissions reductions in the province.

In developing management options for the province, some assumptions were required as to the criteria to be used in assessing those options. The scope of the project was not intended to include a complete socio-economic evaluation but cost and other considerations would have to be taken into account for our report to be of value to you.

In developing the management options in this chapter, the factors incorporated in the analysis are:

- Phase-out dates for CFCs and the extent of HCFC replacement.
- Demands for recycled material.
- Costs of options to consumers, industry and to government for administration.
- Enforceability including expected compliance.
- Acceptability by the public or specialized groups such as insurers in the case of halon.
- Compatibility with other regulations.

With respect to priorities, government should focus on the 3R's—i.e., reduction is the first priority, followed by reuse and recycling. At the same time, all levels of government should make a commitment to lead by way of example. With the development of progressive purchasing policies, requirements for service contractors, and so on, government will be in a strong position to develop and implement appropriate regulations with industry.

B. Approaches for reducing consumption

The intent of the management options being considered in this section is to contribute to an accelerated schedule of consumption reductions and to reduce emissions on a continuing basis. As indicated above, a number of factors must be taken into account in developing these options. The first step then is to apply these criteria and decide on the sectors that will be regulated and the extent of regulation. The sequence of events to accomplish this is:

- Determine if sector is to be regulated.
- Develop information reporting requirements and forms to establish baseline quantities.
- Establish sectoral consumption reduction schedules.
- Develop monitoring framework to ensure compliance with reduction schedules.
- Develop regulations to support these regulatory initiatives.
- Promote education and training programs as needed.

Our assessment is that the most important factor in determining effective policies for British Columbia is the extent to which industry sectors are reducing consumption and emissions under the existing regulatory framework. The Minister of the Environment for Canada has announced the following phase-out schedule for CFCs:[1]

- Eliminate by 1995 in rigid foams.
- Eliminate by 1993 in flexible foams.
- Eliminate by 1995 model year in automobile and light truck air conditioning.
- Eliminate in solvent cleaning applications by 1994.
- Eliminate in sterilant gas by 1994.

In addition, Environment Canada has drafted regulations limiting the use of Halon 1211 in portable fire extinguishers with exemptions for certain critical uses. What are the most useful policy approaches to support this regulatory framework that is already in place?

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[1] *This schedule is, of course, in addition to the overall CFC phase-out date of 1997. Further, it has not been confirmed as of the date of writing.*

The most obvious starting point is exclusions within this list shown above. There is no substance-specific timetable[1] for any of the following:

- Most of the refrigeration and air conditioning sector.
- Halon 1301 systems.
- Methyl chloroform.
- Carbon tetrachloride.

In addition to this list, it may be useful to consider the rigid foam sector for more careful scrutiny. The existing federal initiative treats this as a single sector but as the analysis in this report has shown, this is not correct. There are essentially three sub-sectors to deal with here and each has a different planned reduction schedule. The 1995 date may be quite appropriate for polyurethane foam particularly in poured and sprayed applications but extruded polystyrene and phenolic foam can meet a more stringent schedule. The evidence that we have accumulated suggests that producers of these latter two foams can complete their plans to replace CFCs during 1993. British Columbia's single largest foam manufacturer has already switched its polystyrene plant to an HCFC-22 system.

In addition, it may be useful to develop an approach within the government of British Columbia to meet the target above for sterilant gas. The problem here is concentrated within the hospital sector and a Joint Committee including Environment, Health and representatives from the hospital community could assist hospitals in British Columbia in reducing consumption more quickly.

C. Develop reporting requirements

To support the development of sectoral consumption reduction policies, the most important standards to develop relate to reporting on use patterns. This highlights the importance of selecting sectors to regulate carefully. Reporting on consumption by individual users within sectors imposes a significant regulatory burden on the private sector and involves substantial public sector costs as well. However, if regulations of this kind are to be implemented, baseline quantities for each user must be established and consumption reductions must be monitored annually relative to this baseline and the sector reduction schedule.

In this project, we have developed estimates of consumption within sectors and in some cases, have obtained data from users directly. However, it has not been possible within the scope of this project and on a purely voluntary basis to establish a complete inventory. Some users, in fact, refused to provide data and a regulatory requirement appears to be the only way to get the data that would be required for regulatory purposes.

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[1] *Other than the timetable required under the revised Montreal Protocol.*

D. Develop sectoral reduction policies

Assume that the base year data collected as described in section C above are for 1991. The data would be in terms of the consumption of specific CFCs and the firm would then be assigned a baseline consumption quantity. To be consistent with the Montreal Protocol, this baseline quantity should be defined in ODP units meaning that it would be the sum of each quantity of CFC multiplied by its ODP. For example, if a firm used 10 tonnes of CFC-12 with an ODP of 1.0 and 10 tonnes of CFC-113 with an ODP of 0.8, its consumption baseline would be 18 tonnes measured in units of ODP.

Based on an assessment by the British Columbia Environment Ministry of how stringent regulations within the province should be, a reduction schedule would be developed ending with the year of complete phase-out. As a hypothetical example,the schedule for rigid polystyrene insulation foam might involve a reduction to 60% of 1991 consumption in 1992, 30% in 1993 and zero thereafter. Schedules of this kind should be developed in consultation with users in each sector to assess more clearly the costs associated with differing degrees of stringency. Note that schedules relate to sectors rather than substances (e.g., CFC-12) because technically feasible reduction schedules are sector-specific.

E. Initiatives in provincial ministries and related institutions

In the area of ozone-depleting greenhouse gases, the federal, provincial and municipal governments can play an important role in dealing with both consumption and emissions in the province by establishing themselves as model institutions. This approach has been taken already by some firms in the private sector in announcing a corporate commitment to the earliest possible elimination of these substances. We regard this as a potentially important role for all three levels of government to play. Results can be more immediate when implemented by the appropriate level of government within its own jurisdiction and will support whatever regulatory initiatives are developed for the private sector. As well, there may be some direct spillover benefits if particular policies developed by government can be applied as well by the private sector.

The broad outline of such a provincial strategy can be described in terms of the following points:

- Define units within which responsibility for policies is to be assigned. For example, the Education Ministry would be responsible for developing a program within the Ministry itself but would also require the units that it supports such as school boards to do the same.

- Develop a detailed assessment within each unit of consumption and banks of ozone-depleting substances. New construction and the types of insulation to be used could be specified. Policies for dealing with used refrigerators and policies of dealing only with air conditioning and refrigeration contractors with

recycle facilities would promote the growth of such facilities. Halon portable fire extinguishers (1211) are presumably no longer being purchased but many are certain to be in the existing inventory in many areas. Evidence from other jurisdictions shows that there will be many such units in service where other types of units would work as well. These units could be retired so that no emissions result and recycled for essential aviation uses or destroyed. We are not aware of any such systems in operation at this time.

- Develop specific plans and timetables within each of these units to be "CFC-free" with similar programs for the related substances.

- Develop a reporting system to British Columbia Environment so that progress can be monitored and the results used to indicate to other users the progress that can be made with such programs.

There are clear benefits of such initiatives in a variety of dimensions. Whatever regulatory strategies are proposed, they will be more palatable if the government first shows the resolve to put its own house in order. In the area of recycling, government can provide direct results but can also support the recycling industry by contracting only with firms that are committed to and have invested in the necessary types of recycling equipment.

Government, government agencies and firms regulated by government such as B.C. Hydro and B.C. Tel have been major purchasers of halon fire protection systems. Some essential uses may remain but standards are necessary to ensure that other fire projections alternatives are used wherever feasible. Systems that are now in place where alternatives are feasible can be dismantled and the halon 1301 can be recycled for use in essential areas elsewhere, reducing the quantity of new halon being installed in the province.

Codes of practice have been described elsewhere in this report for refrigeration and air conditioning but this approach can be applied in the fire protection area as well. The fire protection community is already active in this area in some jurisdictions (e.g., recapture of Halon 1301 in decommissioned systems in Ontario and British Columbia), but these initiatives can be reviewed for their adequacy.

F. Develop recycling initiatives

In this section, we assess potential management options in the area of reclamation and recycling. Based on current technology, these activities could be carried out in many areas but we focus primarily on areas where cost-effectiveness is greatest. We recognize that efforts to establish initiatives in this area are already in progress through a joint federal-provincial group but effective provincial policies will not be inconsistent with these initiatives.

Reclamation and recycling policies offer a number of advantages in dealing with ozone-depleting greenhouse gases. Effective polices in this area can be expected to contribute in the following ways:

- Both consumption and emissions are reduced.
- Contributes to the achievement of more stringent reduction targets.
- Initiatives of this kind will be essential for meeting service demands after phase-out.
- As production declines and is ultimately phased out, the benefit-cost picture for recycling becomes increasingly favourable.

The areas in which reclamation and recycling policies can be implemented most effectively are:

- Refrigeration and air conditioning.
- Halon 1301 systems.
- Solvents; CFC-113 and methyl chloroform.
- Sterilant gas.

Previous sections of this report have dealt in more detail with the potential role for recycling in each of these sectors. An area like sterilant gas has significant potential in this respect because so much of current consumption occurs in provincial hospitals. In this section, however, we focus primarily on refrigeration and air conditioning. This is because the quantities are so large in this sector that recycling initiatives will have the greatest benefits here.

In the refrigeration and air conditioning sector, recycling initiatives appear necessary if plans for early phase-outs of CFCs are to be achieved without generating very high costs. As an example, consider the phase-out date for CFCs of 1997 that has been announced by Environment Canada. New equipment that is being installed now contains CFC refrigerants. This will likely continue for new residential refrigerators, for example, until 1995. How will units charged with CFC-12 purchased new in 1995 and requiring service in 1998 be repaired? After new production is phased out, the answer must be that these units are serviced with reclaimed CFC-12 that has been recycled.

The dimensions of the service demand problem following production phase-out for new CFCs is shown in Exhibit V-1. This exhibit shows estimated lifespans for various types of refrigeration equipment. Depending on the specific assumptions that are made about the pattern of installation of CFC-using equipment before 1997, service demands could be substantial and could continue for nearly 20 years. If adequate supplies of recycled CFCs are not available, the costs of scrapping this equipment prematurely will be very high. The

potential benefit of effective measures in this area (e.g., recycling) should make this an attractive policy for the British Columbia government to implement.

Exhibit V-1
Lifespans of refrigeration and air conditioning equipment

Equipment Type	Lifespan (years)
Domestic refrigeration	12
Mobile air conditioning	8
Refrigerated transportation	12
Industrial refrigeration	20
Commercial chillers	20
Cold storage/food refrigeration	15
Retail refrigeration	8

Source: Refrigeration, Air Conditioning and Heat Pumps Technical Options Report, (UNEP, 1989).

One perspective on how a CFC reclamation/recycling program could be operated is provided in the report prepared by the Federal-Provincial Working Group on Controls Harmonization titled **National Action Plan for Recovery and Recycle of CFCs**. The report is directed primarily to refrigeration and air conditioning but the principles are applicable to other areas as well. In this plan, the essential steps are:

- Develop the appropriate incentive and regulatory structure to promote recovery and recycling.
- Create an adequate infrastructure to contribute to reclamation, transport, recycling and disposal of CFCs.
- Develop an information and training program to provide support from the public and to develop the capacity in the CFC service sector to carry out an effective program in this area.

Although initiatives in this area are already in progress, it is our understanding that there is no commercial facility in British Columbia to recycle reclaimed CFCs in large quantities. Small machines are available as are "vampire" units that recycle on site. Various jurisdictions have developed regulations dealing with recycling but there is not yet a single model that can be applied directly. The data on banked quantities in the companion volume to this report provides a useful starting point in developing a recycling strategy for British Columbia.

VI

Forecast Emissions, Consumption And Banked Quantities

We developed a table (Exhibit VI-1) that presents an emissions forecast for the years 1990 to 2010. We have combined the estimated emissions from the companion report by application to produce the total emissions by substance for 1990.

Our estimate of emissions for British Columbia is based on the status quo—i.e., continuing the existing efforts to comply with the Montreal Protocol with policies adopted by the federal government and private sector. In the event that new legislation or regulations are adopted in British Columbia, our estimates will have to be revised accordingly. For example, if a provincial ban is placed on the use of CFC-113 as a solvent in 1992, the emission figures will become zero two years earlier than we anticipate.

We provide estimated ODP weighted emissions and GWP weighted emissions for the various substances in Exhibit VI-2 and Exhibit VI-3. These exhibits show that with the current policies adopted by the federal government and private sector, ODPs and GWPs in the year 2000 will be about 5%-10% of the 1990 level. The combined 1990 ODP is 1,037 compared to 58 in 2000 plus that contributed by the "other" HCFCs. The 1990 GWP of 628 drops to 54 plus that of the "other" HCFCs.

These levels can be further reduced and/or reduced at a faster rate if new policies or regulations are put in place.

Exhibits VI-4 and VI-5 present forecasts for consumption and banked quantities, respectively, also to the year 2010. The consumption figures provide for a total phase out of halons and CTC by the year 2000, MCF in 2005 and all CFCs by 2010. The drop in CFC consumption is more than made up for by the rapid increase in consumption of HCFCs.

The banked forecast (Exhibit VI-5) is somewhat biased in that substances banked in CFCs are not included in the table whereas they are included for the HCFCs. This is because it is impossible to estimate both the current quantity banked in CFC blown rigid foams, etc. and the extent to which HCFCs will be banked in various products in the future. This accounts, to some degree, for the rapid increase in the banked quantity of HCFCs to the year 2010.

The large bank of HCFCs is also due to the expected decrease in the rate of emissions. For all substances except CFC-11 we have assumed a decrease in rate of emissions. In most

cases we assume an emission rate of 20% of banked quantity in 1990, dropping at the rate of 1% per year and stabilizing at 10% in the year 2000.

Our estimated rate of change in each substance is based on projections provided by industry and our own experience in dealing with these issues at the national level.

CTC emissions are expected to continue at a rate of 4% of annual consumption. MCF emissions equal 80% of consumption in 1990 and decrease at the rate of 5% per year until stabilizing at a rate of 50% per year. Halon 1211 emissions will occur at 10% of banked quantity and the total bank will decrease at the rate of 10% per year. Halon 1301 will be decommissioned at the rate of 10% per year from 1996 to 2000 and 20% per year thereafter, after increasing slightly to 1995. There are some minor adjustments to the above assumptions.

CFC and HCFC decreases and increases are based on discussions with DuPont and are driven as a percentage of the base value in 1990.

In all relevant cases, recycled and reused quantities are not considered as re-entering the "consumption" stream. Thus, substance reuse is in addition to the consumption data presented in Exhibit VI-4. Further, the forecasts assume that the proposed phase-out dates for substances by sector, as identified on page 44 of this report, are in fact promulgated.

Exhibit VI-1.
Emissions Forecast: 1990 to 2010

	Substance									
Year	CFC-11	CFC-12	CFC-113	CFC-115	HCFC-22	Other HCFC's	CTC	MCF	Halon 1211	Halon 1301
1990	47	483	10	29	150	0	0.08	280	41	32
1991	38	459	8	28	158	0	0.08	252	29	29
1992	28	435	5	26	170	8	0.07	224	21	26
1993	24	411	3	23	191	17	0.06	196	16	22
1994	14	338	1	17	201	22	0.04	168	12	19
1995	12	290	0	12	218	29	0.02	140	8.2	16
1996	9.4	242	0	8.7	231	35	0.01	112	4.1	13
1997	7.1	193	0	5.8	233	35	0.01	84	3.1	9.6
1998	4.7	97	0	2.9	234	36	0.004	56	2.1	6.4
1999	3.3	34	0	2.0	236	37	0.002	28	1.0	3.2
2000	2.4	24	0	1.5	240	39	0.000	14	0.3	1.6
2005	0.9	10	0	0.6	260	47	0.000	0	0.0	0.3
2010	0.0	0	0	0.0	288	59	0.000	0	0.0	0.0

Source: PMS&K estimates

Exhibit VI-3
Estimated Absolute, ODP Weighted and GWP Weighted Emissions of Halons, CTC and MCF in British Columbia (tonnes)

Year	Halon 1211	ODP	GWP	Halon 1301	ODP	GWP	CTC	ODP	GWP	MCF	ODP	GWP
1990	41	123	-	32	320	26	0.08	0.09	0.01	280	31	2.1
1991	29	86	-	29	288	23	0.08	0.09	0.01	252	28	1.9
1992	21	62	-	26	256	20	0.07	0.08	0.01	224	25	1.7
1993	16	49	-	22	224	18	0.06	0.06	0.01	196	22	1.5
1994	12	37	-	19	192	15	0.04	0.04	<0.01	168	18	1.2
1995	8.2	25	-	16	160	13	0.02	0.02	<0.01	140	15	1.0
1996	4.1	12	-	13	128	10	0.01	0.01	<0.01	112	12	0.8
1997	3.1	9	-	9.6	96	7.7	0.01	0.01	<0.01	84	9.2	0.6
1998	2.1	6.2	-	6.4	64	5.1	<0.01	<0.01	<0.01	56	6.2	0.4
1999	1.0	3.1	-	3.2	32	2.6	<0.01	<0.01	<0.01	28	3.1	0.2
2000	0.3	0.9	-	1.6	16	1.3	0.00	0.00	0.00	14	1.5	0.1
2005	0.0	0.0	-	0.3	3.2	0.3	0.00	0.00	0.00	0	0.0	0.0
2010	0.0	0.0	-	0.0	0.0	0.0	0.00	0.00	0.00	0	0.0	0.0

Source: PMS&K estimates

Exhibit VI-2
Estimated Absolute, ODP Weighted and GWP Weighted Emissions of CFCs and HCFCs in British Columbia (tonnes)

	Substance															
Year	CFC-11	ODP	GWP	CFC-12	ODP	GWP	CFC-113	ODP	GWP	CFC-115	ODP	GWP	HCFC-22	ODP	GWP	Other* HCFC's
1990	47	47	16	483	483	483	10	8.0	4.9	29	17	81	150	8	15	0
1991	38	38	13	459	459	459	8.0	6.4	3.9	28	17	77	158	8	15	0
1992	28	28	10	435	435	435	5.0	4.0	2.5	26	16	73	170	8	17	8
1993	24	24	8	411	411	411	3.0	2.4	1.5	23	14	65	191	10	19	17
1994	14	14	4.8	338	338	338	1.0	0.8	0.5	17	10	49	201	10	20	22
1995	12	12	4.0	290	290	290	0.0	0.0	0.0	12	7.0	32	218	11	21	29
1996	9.4	9.4	3.2	242	242	242	0.0	0.0	0.0	8.7	5.2	24	231	12	23	35
1997	7.1	7.1	2.4	193	193	193	0.0	0.0	0.0	5.8	3.5	16	233	12	23	35
1998	4.7	4.7	1.6	97	97	97	0.0	0.0	0.0	2.9	1.7	8.1	234	12	23	36
1999	3.3	3.3	1.1	34	34	34	0.0	0.0	0.0	2.0	1.2	5.7	236	12	23	37
2000	2.4	2.4	0.8	24	24	24	0.0	0.0	0.0	1.5	0.9	4.1	240	12	24	39
2005	0.9	0.9	0.3	10	10	10	0.0	0.0	0.0	0.6	0.3	1.6	260	13	25	47
2010	0.0	0.0	0.0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	288	14	28	59

**Note - it is not possible to estimate the ODP or GWP due to the wide number of HCFCs that may be employed.*

Source: PMS&K estimates

Exhibit VI-5
Banked Forecast: 1990 to 2010*

Year	Substance									
	CFC-11	CFC-12	CFC-113	CFC-115	HCFC-22	Other HCFC's	CTC	MCF	Halon 1211	Halon 1301
1990	119	1,586	0	145	604	0	0	0	300	210
1991	107	1,530	0	157	991	0	0	0	287	221
1992	95	1,553	0	169	1,413	38	0	0	205	228
1993	83	1,579	0	179	1,891	123	0	0	164	232
1994	71	1,409	0	187	2,399	238	0	0	123	235
1995	60	1,380	0	192	2,952	401	0	0	82	236
1996	48	1,150	0	196	3,544	615	0	0	41	212
1997	36	1,073	0	199	4,144	851	0	0	31	191
1998	24	690	0	200	4,753	1,115	0	0	21	172
1999	12	338	0	190	5,371	1,412	0	0	10	155
2000	8	242	0	180	6,005	1,759	0	0	3	139
2005	2	97	0	100	9,188	3,686	0	0	0	46
2010	0	0	0	20	12,380	6,078	0	0	0	15

**Note - does not include banked quantity in products (e.g. foams) for CFC's, but does include banked quantity in products made with HCFC's.*

Source: PMS&K estimates

Exhibit VI-4
Consumption Forecast: 1990 to 2010

	Substance									
Year	CFC-11	CFC-12	CFC-113	CFC-115	HCFC-22	Other HCFC's	CTC	MCF	Halon 1211	Halon 1301
1990	118	465	20	42	514	0	2.0	350	33	43
1991	94	442	16	40	545	0	2.0	336	23	36
1992	71	419	10	38	591	46	1.8	320	16	30
1993	59	395	6	34	668	102	1.4	302	13	25
1994	35	326	2	25	709	137	1.0	280	10	20
1995	30	279	0	17	771	193	0.40	255	6.6	16
1996	24	233	0	13	822	248	0.30	224	2.1	13
1997	18	186	0	8.4	833	272	0.20	168	1.5	9.6
1998	12	93	0	4.2	843	300	0.10	112	1.0	6.4
1999	8.3	33	0	2.9	853	333	0.05	56	0.5	3.2
2000	5.9	23	0	2.1	874	386	0.00	28	0.0	0.0
2005	2.4	9.3	0	0.8	900	471	0.00	0.0	0.0	0.0
2010	0.0	0.0	0	0.0	925	592	0.00	0.0	0.0	0.0

Source: PMS&K estimates

Appendix 1

Guidelines Of The Heating Refrigeration And Air Conditioning Institute To Reduce Controlled CFC Emissions

Appendix 1

Guidelines Of The Heating Refrigeration And Air Conditioning Institute To Reduce Controlled CFC Emissions

1. Design new systems for CFC-22 or other lower or non ozone depleting refrigerants

Recognizing that there are certain uses where alternatives are not presently available such as centrifugal chillers, all new industrial and commercial refrigeration and air conditioning systems should be designed to operate on CFC-22 or an alternative refrigerant with lower or no ozone depleting potential.

2. Incorporate receivers and isolating valves in new systems

The design of new installations should incorporate means such as receivers sized to contain the full charge of the system and adequate isolating valves to minimize blow-off and refrigerant loss during service.

3. Do not use CFC-11 or 113 for flushing

The use of CFC-11 and 113 in the flushing of refrigeration and air conditioning systems should be replaced by alternative cleaning methods such as the filter-drier or other available methods.

4. Use receivers during servicing of systems

All refrigeration and air conditioning systems should be pumped-down and contained in a receiving vessel (whether part of the system or separate) so that refrigerant is not vented to atmosphere.

5. Reuse, recover and recycle refrigerants, where possible

Where of acceptable quality, refrigerant should be reused in every case. Where refrigerant is not of an acceptable quality for immediate reuse, then recovery and recycle methods should be carried out, where possible.

6. Replace CFC-12 with environmentally safer refrigerants where feasible

When servicing CFC-12 refrigeration and air conditioning systems, replacement of CFC-12 with environmentally safer refrigerants should be considered where it is practical and recommended by the equipment manufacturer.

7. Pressure test with inert gases and ensure all system piping is tight

Pressure testing of refrigeration and air conditioning systems should not be done with CFC-12 and instead, other available environmentally safe alternates must be used.

8. Do not use one pound cans of refrigerant

The use of one pound refrigerant containers shall be eliminated because of the high percentage of refrigerant loss from the container.

Note: Environment Canada has now regulated with regard to item 8.

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